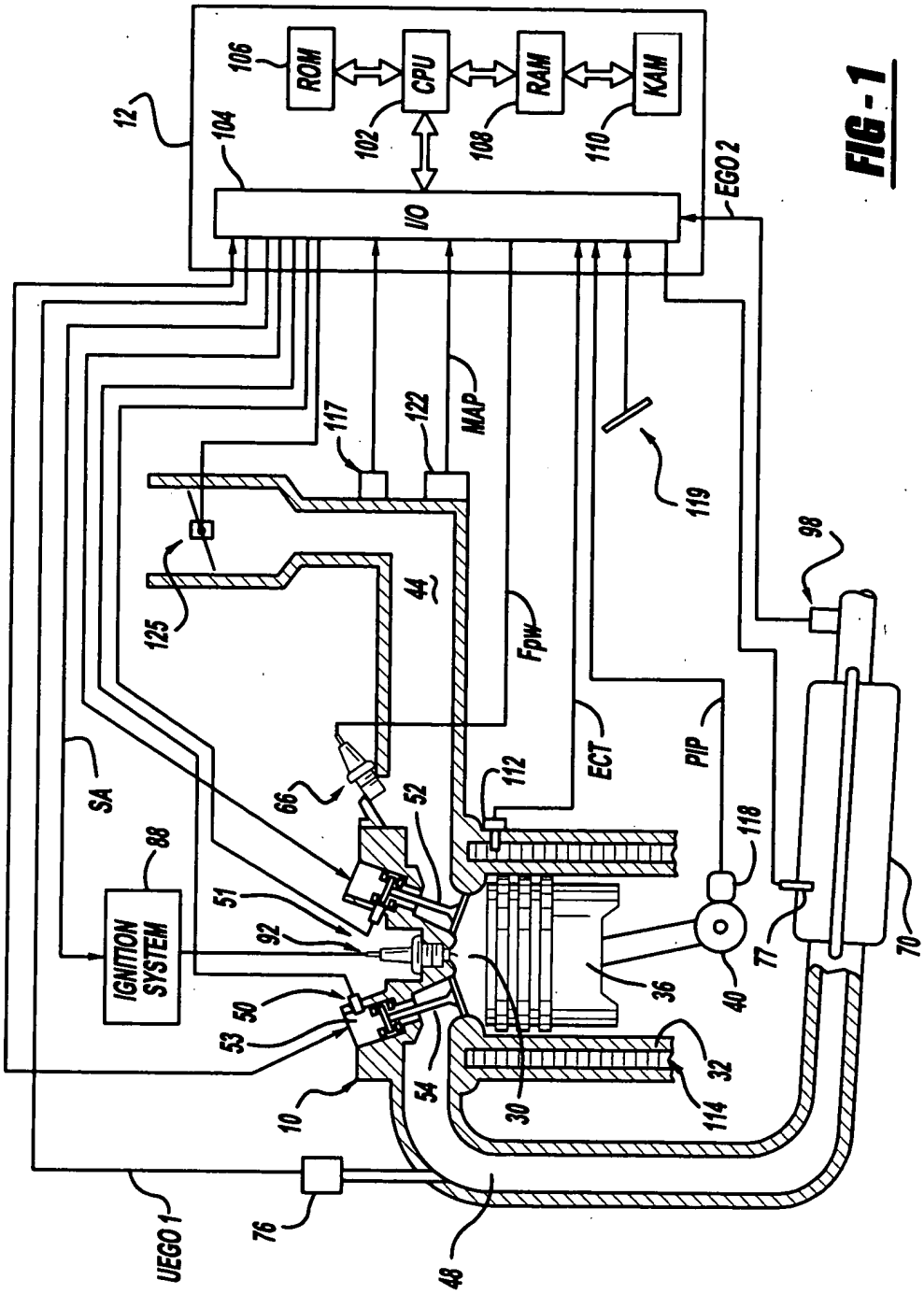
12
104
106
ROM
CPU
RAM
KAM
102
108
110
I/O
EGO 2
MAP
117
122
119
98
125
44
Fpw
ECT
PIP
112
118
SA
66
52
88
IGNITION SYSTEM
51
92
50
53
54
10
30
36
40
77
70
32
114
UEGO 1
76
48

FIG - 1

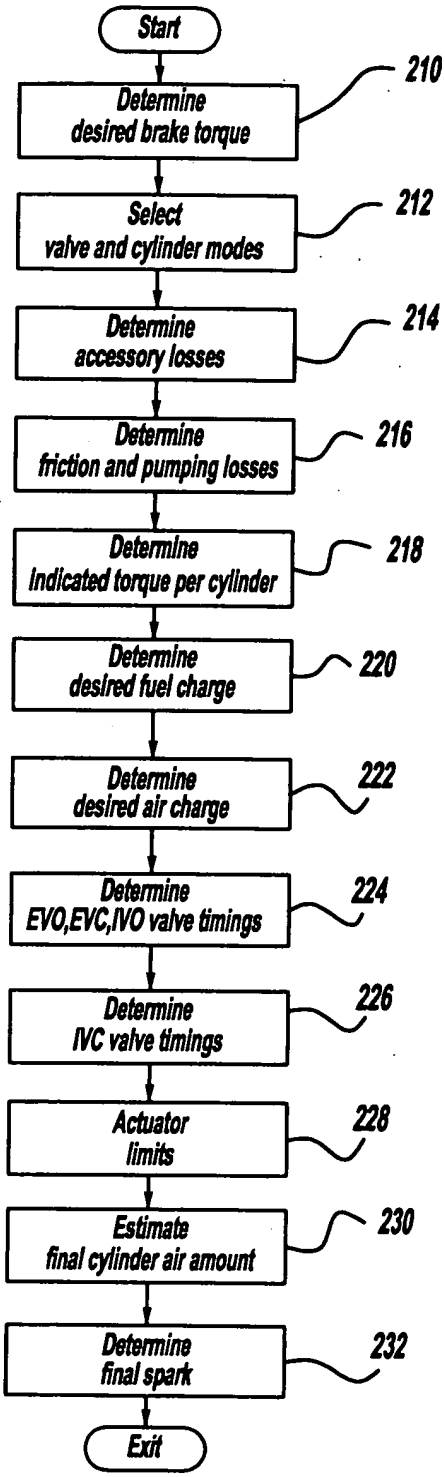
Start
Determine desired brake torque
210
Select valve and cylinder modes
212
Determine accessory losses
214
Determine friction and pumping losses
216
Determine Indicated torque per cylinder
218
Determine desired fuel charge
220
Determine desired air charge
222
Determine EVO,EVC,IVO valve timings
224
Determine IVC valve timings
226
Actuator limits
228
Estimate final cylinder air amount
230
Determine final spark
232
Exit

FIG - 2

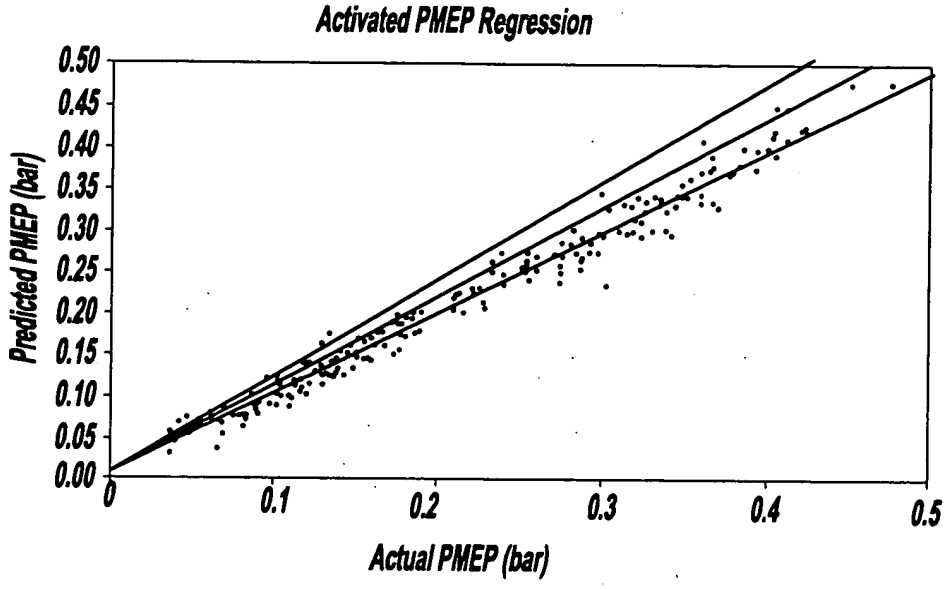
Activated PMEP Regression
Predicted PMEP (bar)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.1
0.2
0.3
0.4
0.5
Actual PMEP (bar)

FIG - 3

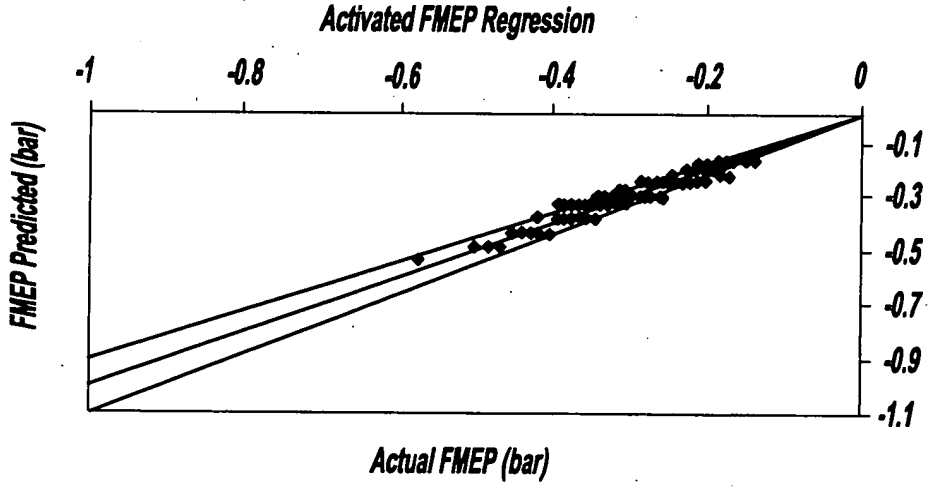
Activated FMEP Regression
FMEP Predicted (bar)
-1
-0.8
-0.6
-0.4
-0.2
0
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
Actual FMEP (bar)

FIG - 4

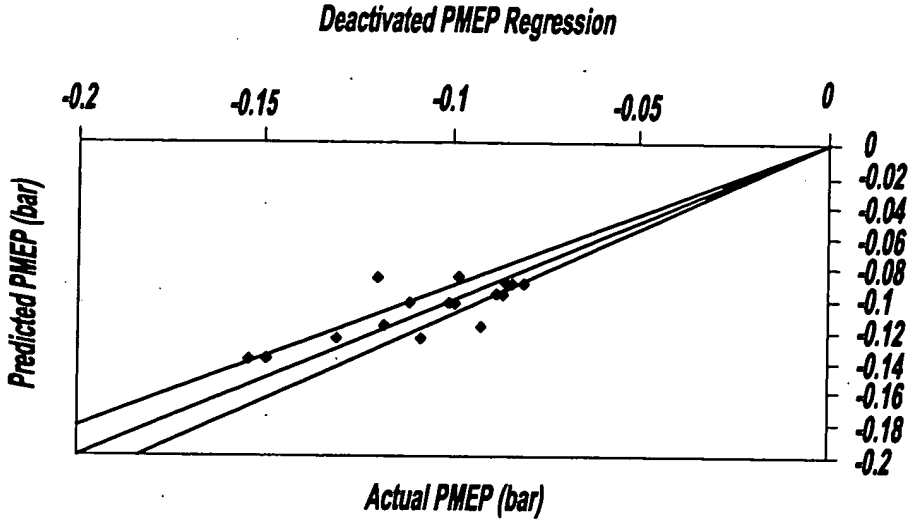
Deactivated PMEP Regression
-0.2
-0.15
-0.1
-0.05
0
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
-0.18
-0.2
Predicted PMEP (bar)
Actual PMEP (bar)

FIG - 5

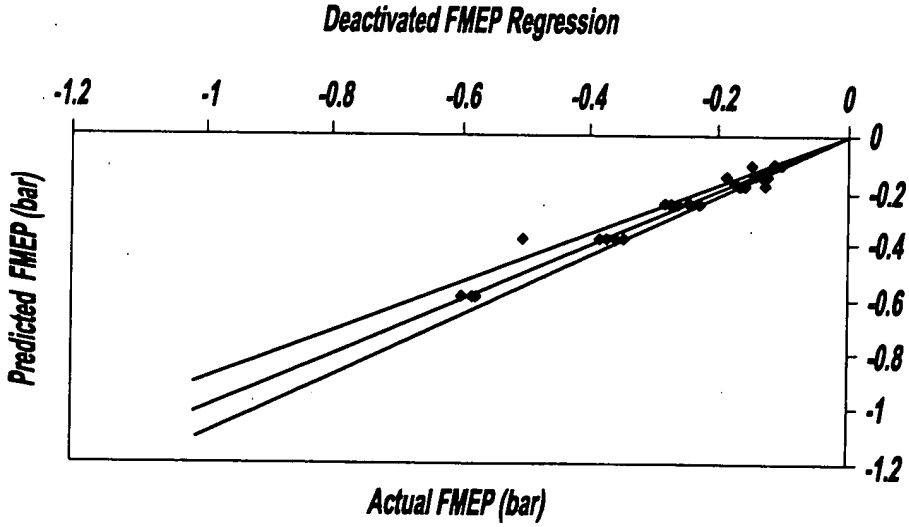
Deactivated FMEP Regression
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
Predicted FMEP (bar)
Actual FMEP (bar)

FIG - 6

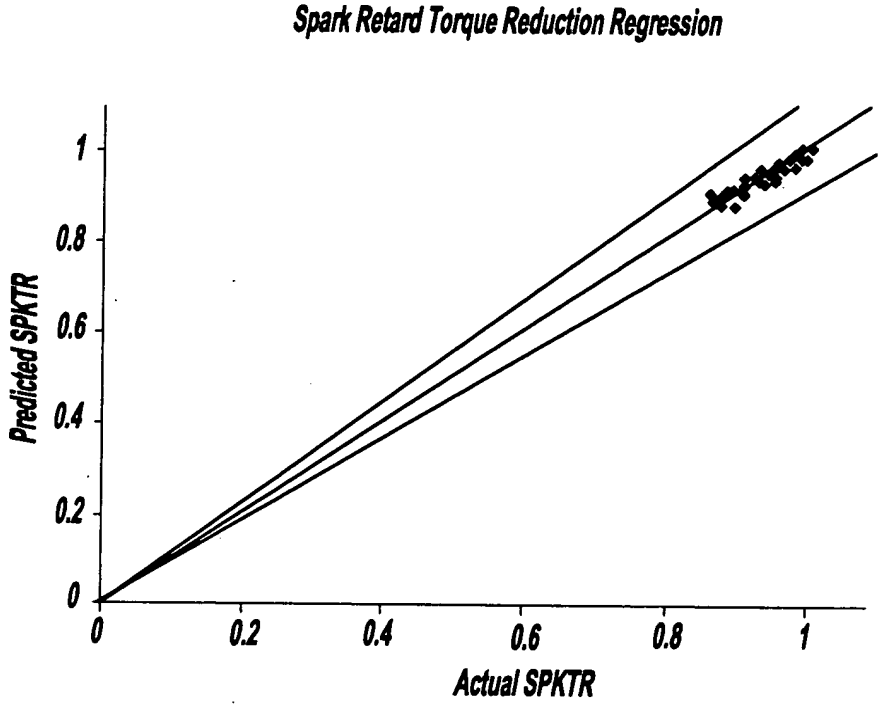
Spark Retard Torque Reduction Regression
Predicted SPKTR
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
Actual SPKTR

FIG - 7

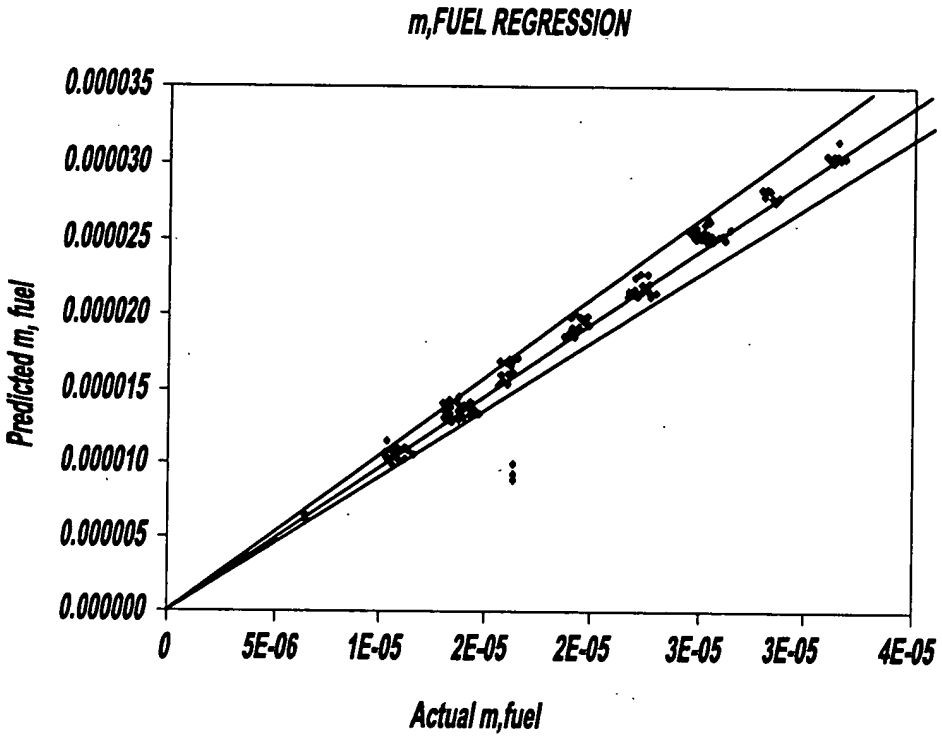
m,FUEL REGRESSION
0.000035
0.000030
0.000025
0.000020
0.000015
0.000010
0.000005
0.000000
Predicted m, fuel
0
5E-06
1E-05
2E-05
2E-05
3E-05
3E-05
4E-05
Actual m,fuel

FIG - 8

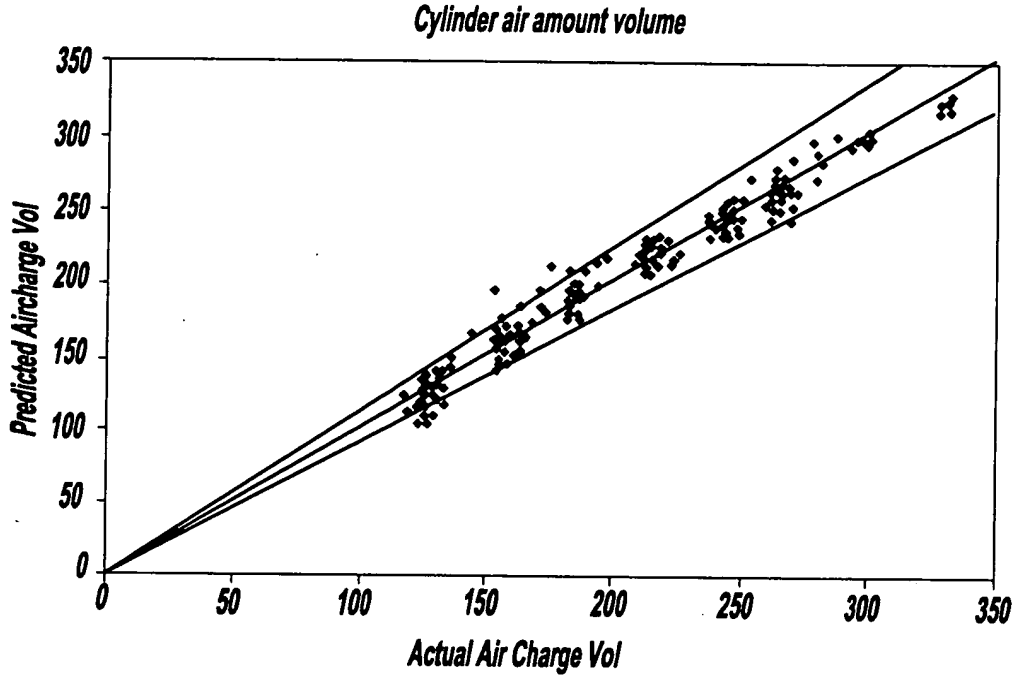
Cylinder air amount volume
Predicted Aircharge Vol
Actual Air Charge Vol
0
50
100
150
200
250
300
350

FIG - 9

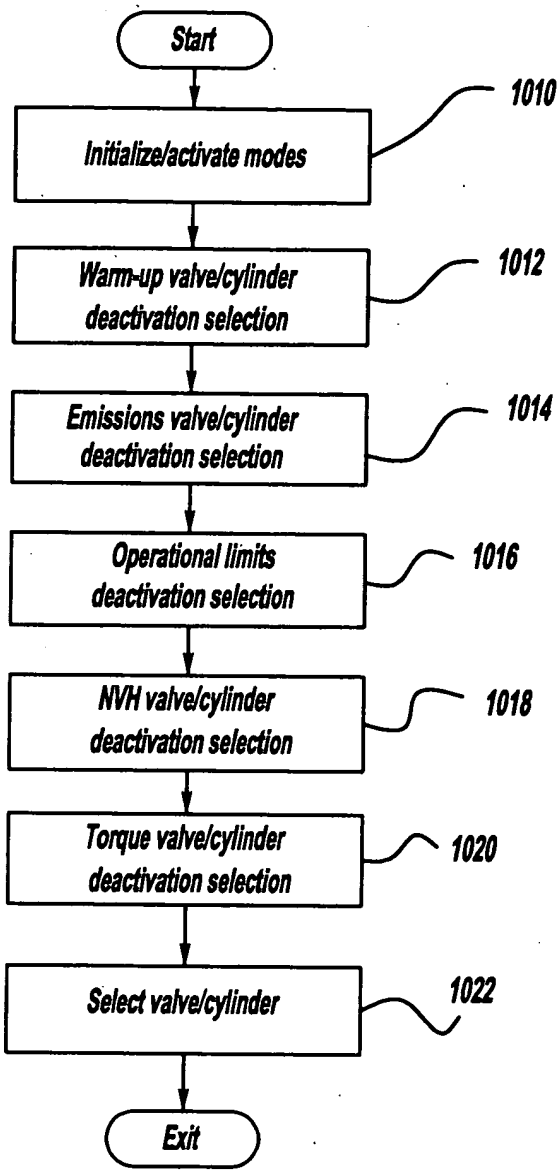
Start
Initialize/activate modes
1010
Warm-up valve/cylinder deactivation selection
1012
Emissions valve/cylinder deactivation selection
1014
Operational limits deactivation selection
1016
NVH valve/cylinder deactivation selection
1018
Torque valve/cylinder deactivation selection
1020
Select valve/cylinder
1022
Exit

FIG - 10

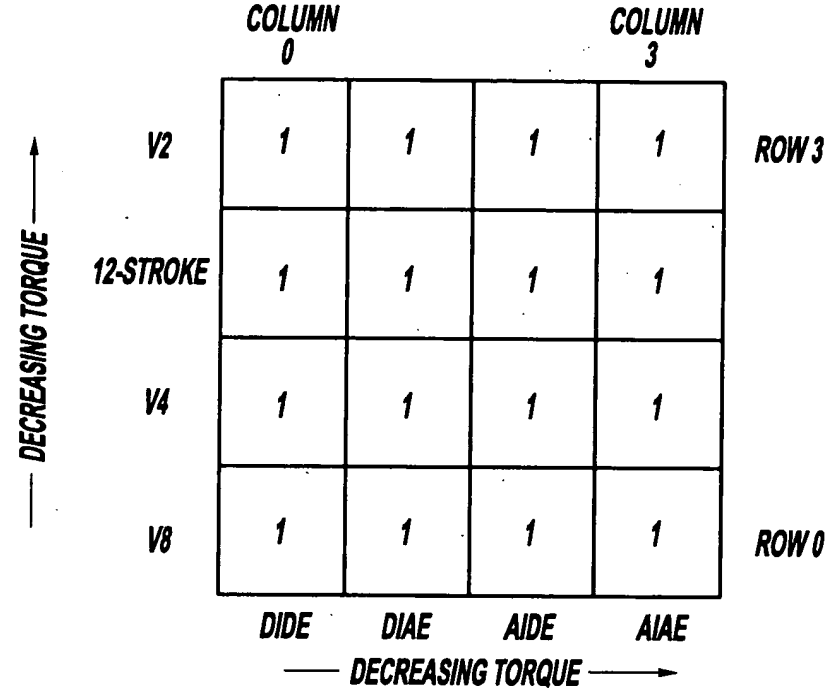
COLUMN 0
COLUMN 3
V2
12-STROKE
V4
V8
ROW 3
ROW 0
1
DECREASING TORQUE
DIDE
DIAE
AIDE
AIAE
DECREASING TORQUE

FIG - 11

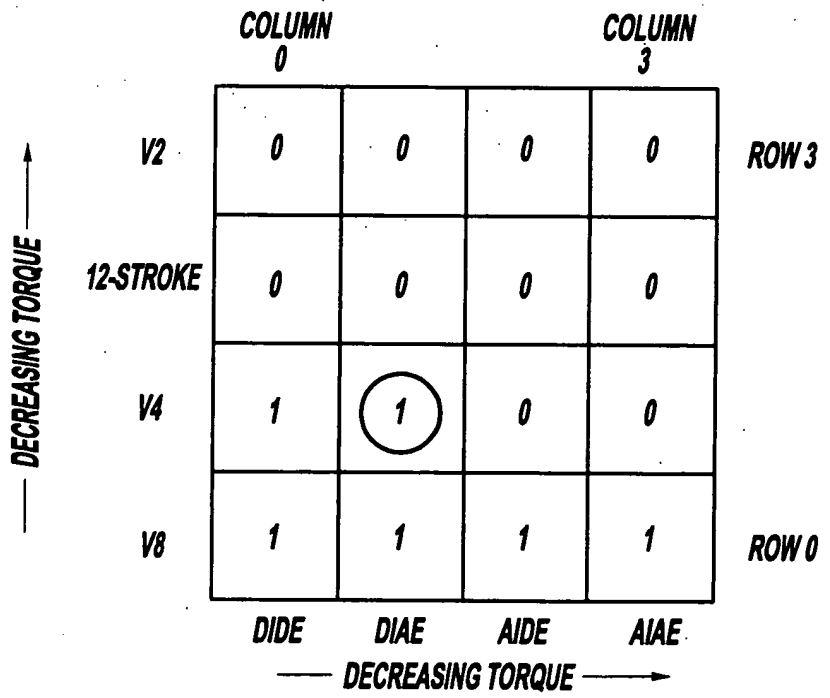
COLUMN 0
COLUMN 3
V2
12-STROKE
V4
V8
ROW 3
ROW 0
0
1
DECREASING TORQUE
DIDE
DIAE
AIDE
AIAE
DECREASING TORQUE

FIG - 12

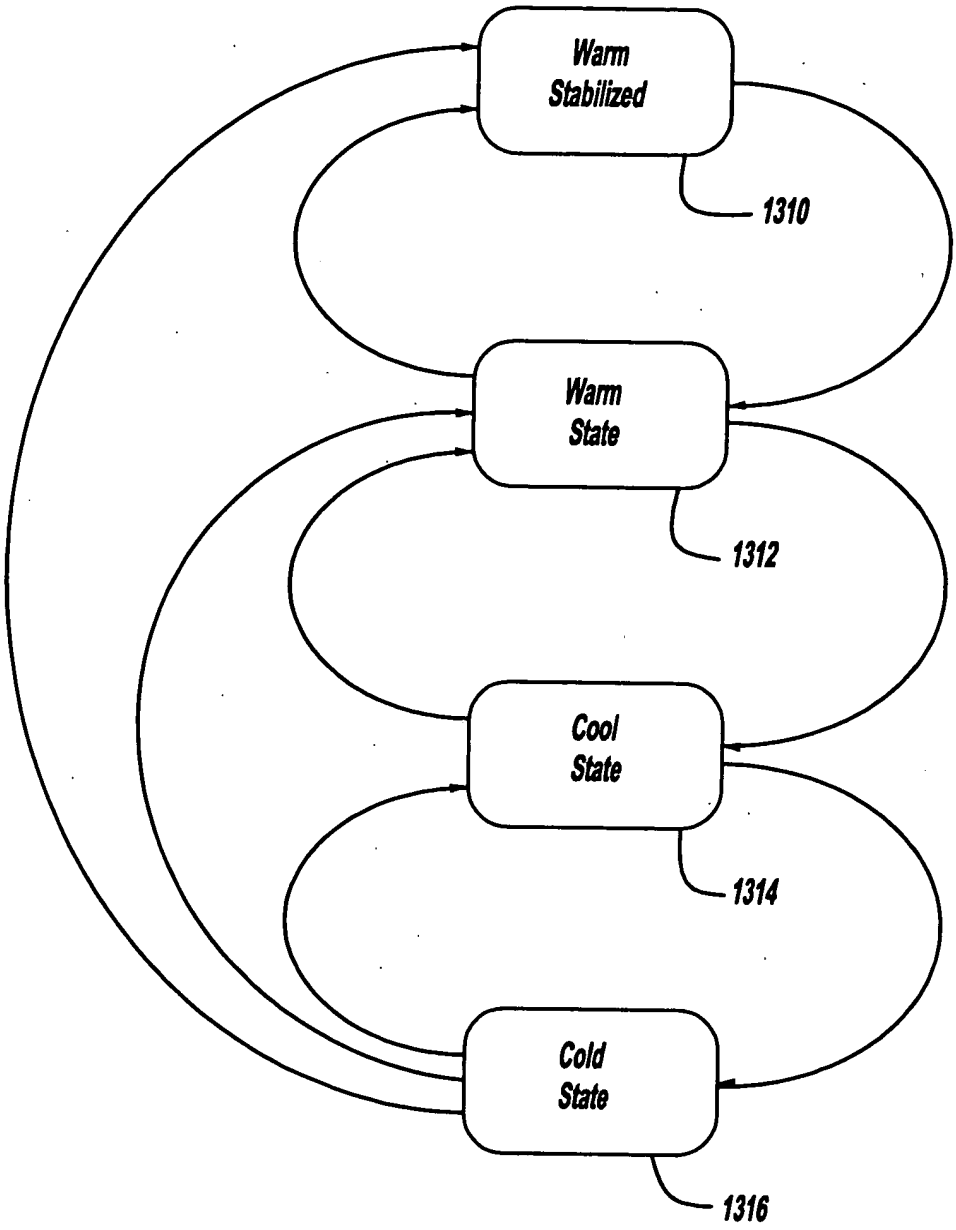
Warm Stabilized
1310
Warm State
1312
Cool State
1314
Cold State
1316

FIG - 13

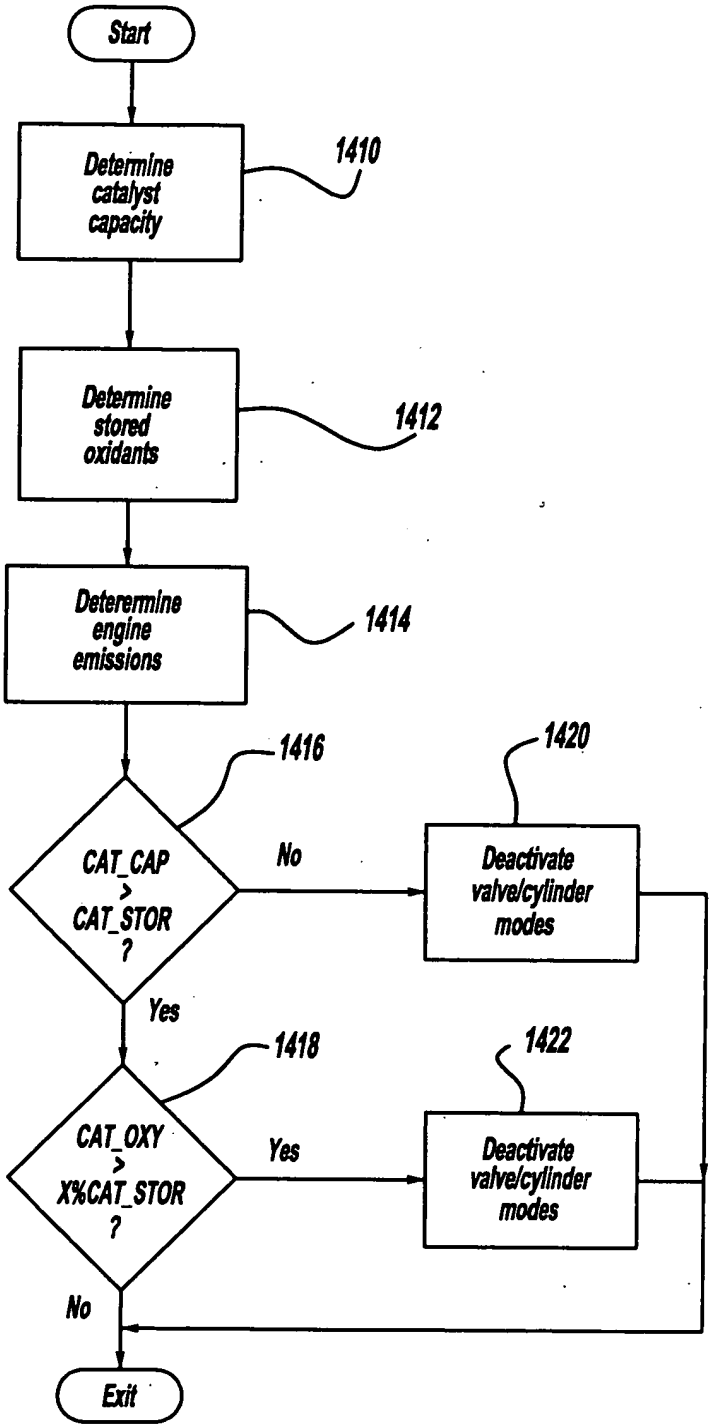
Start
Determine catalyst capacity
1410
Determine stored oxidants
1412
Deterermine engine emissions
1414
1416
CAT_CAP > CAT_STOR ?
No
1420
Deactivate valve/cylinder modes
Yes
1418
CAT_OXY > X%CAT_STOR ?
Yes
1422
Deactivate valve/cylinder modes
No
Exit

FIG - 14

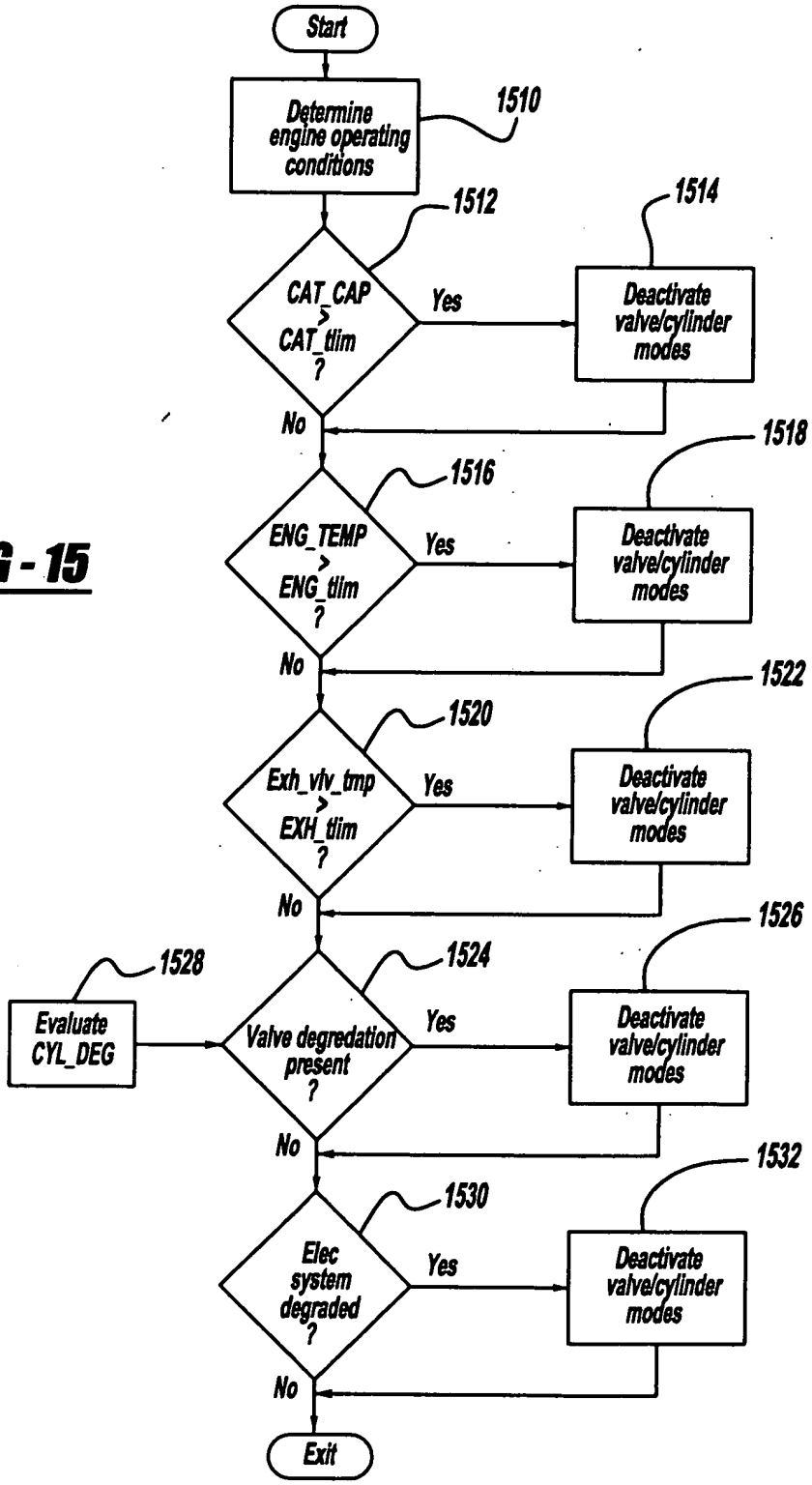
Start
Determine engine operating conditions
1510
CAT_CAP > CAT_tlim ?
1512
Yes
Deactivate valve/cylinder modes
1514
No
ENG_TEMP > ENG_tlim ?
1516
Yes
Deactivate valve/cylinder modes
1518
No
Exh_vlv_tmp > EXH_tlim ?
1520
Yes
Deactivate valve/cylinder modes
1522
No
Valve degredation present ?
1524
Yes
Deactivate valve/cylinder modes
1526
Evaluate CYL_DEG
1528
No
Elec system degraded ?
1530
Yes
Deactivate valve/cylinder modes
1532
No
Exit

FIG - 15

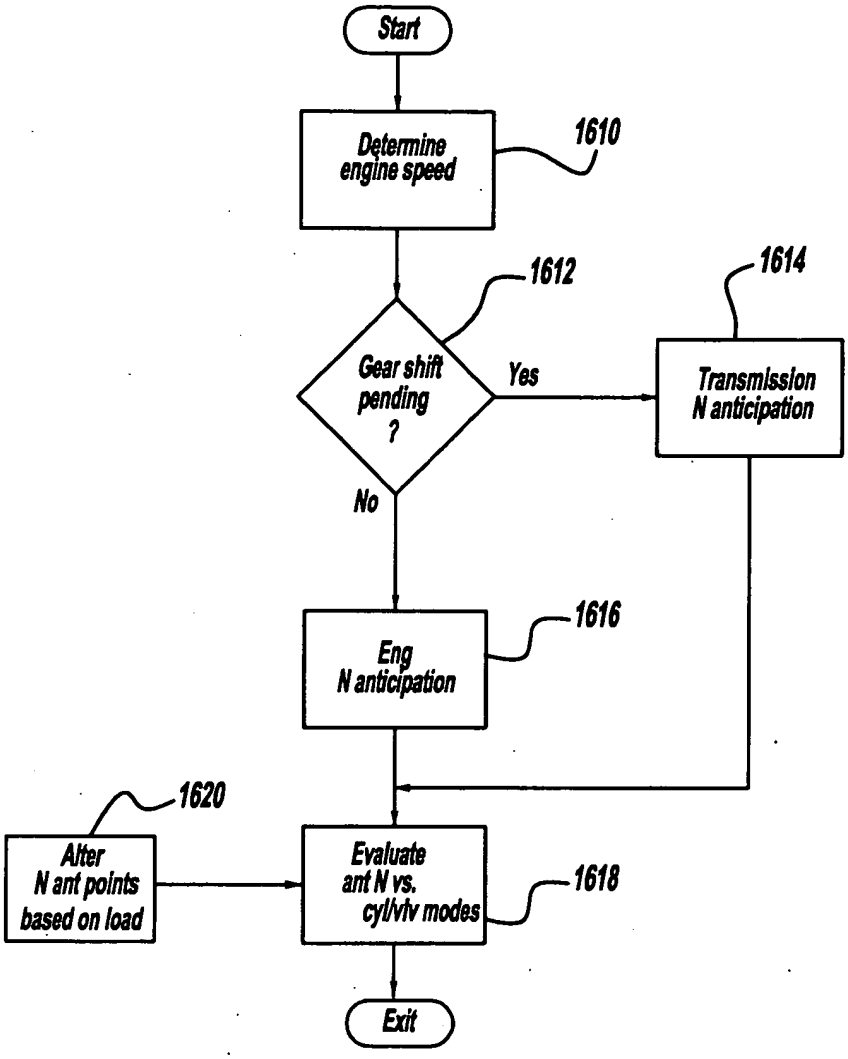
Start
Determine engine speed
1610
1612
Gear shift pending ?
Yes
1614
Transmission N anticipation
No
Eng N anticipation
1616
1620
Alter N ant points based on load
Evaluate ant N vs. cyl/vlv modes
1618
Exit

FIG - 16

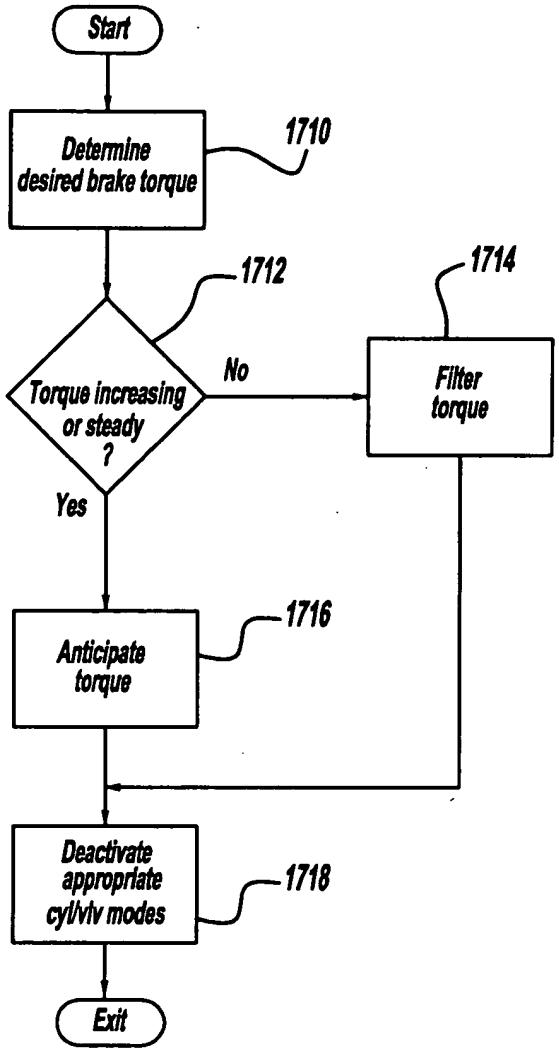
Start
Determine desired brake torque
1710
1712
1714
Torque increasing or steady ?
No
Filter torque
Yes
Anticipate torque
1716
Deactivate appropriate cyl/vlv modes
1718
Exit

FIG - 17

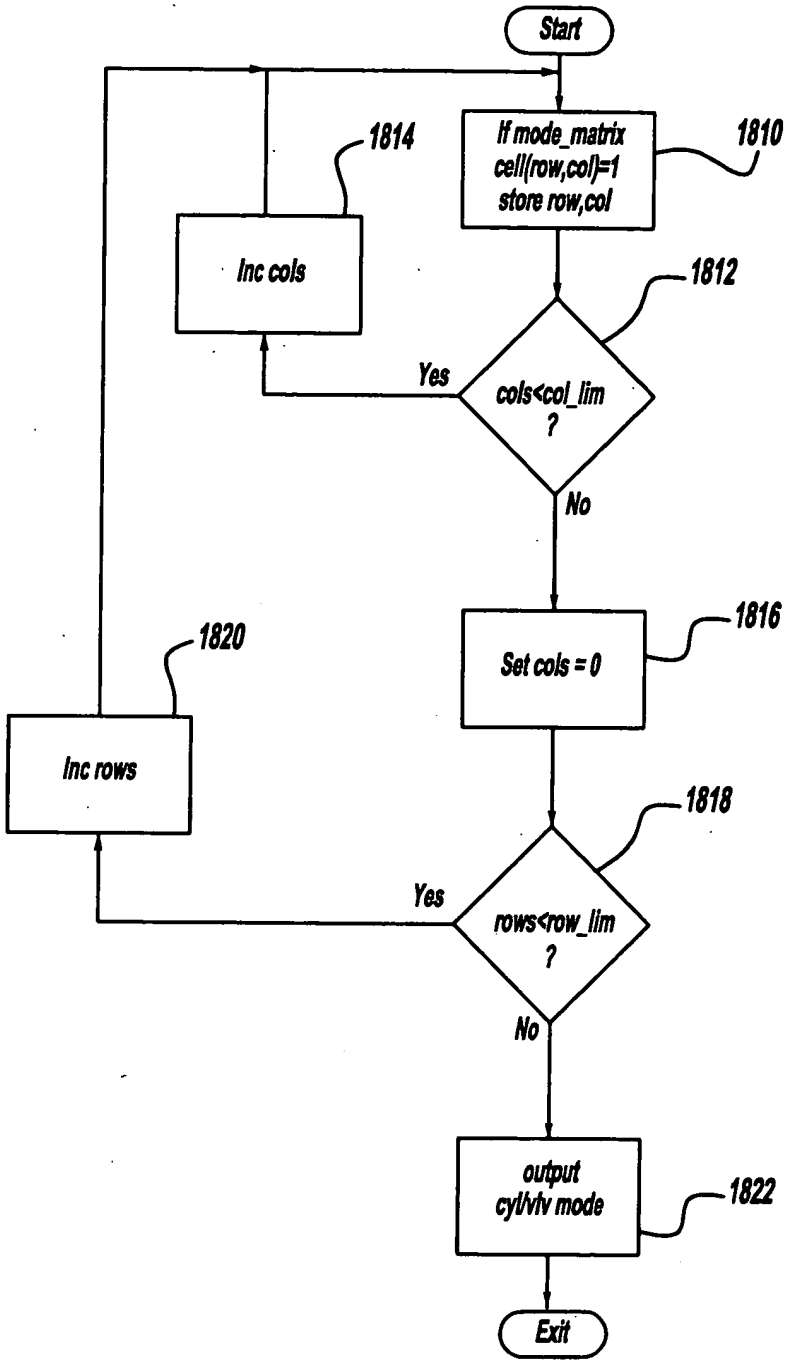
Start
If mode_matrix cell(row,col)=1 store row,col
1810
1814
Inc cols
1812
Yes
cols<col_lim ?
No
1816
Set cols = 0
1820
Inc rows
1818
Yes
rows<row_lim ?
No
output cyl/vlv mode
1822
Exit

FIG - 18

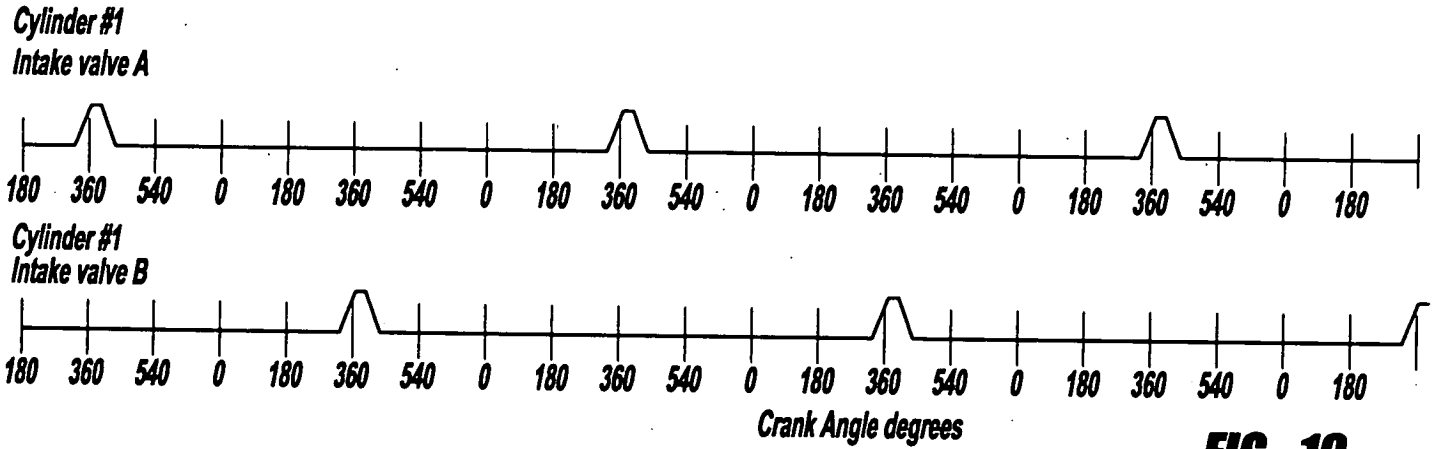
Cylinder #1
Intake valve A
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
Cylinder #1
Intake valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
Crank Angle degrees

FIG - 19

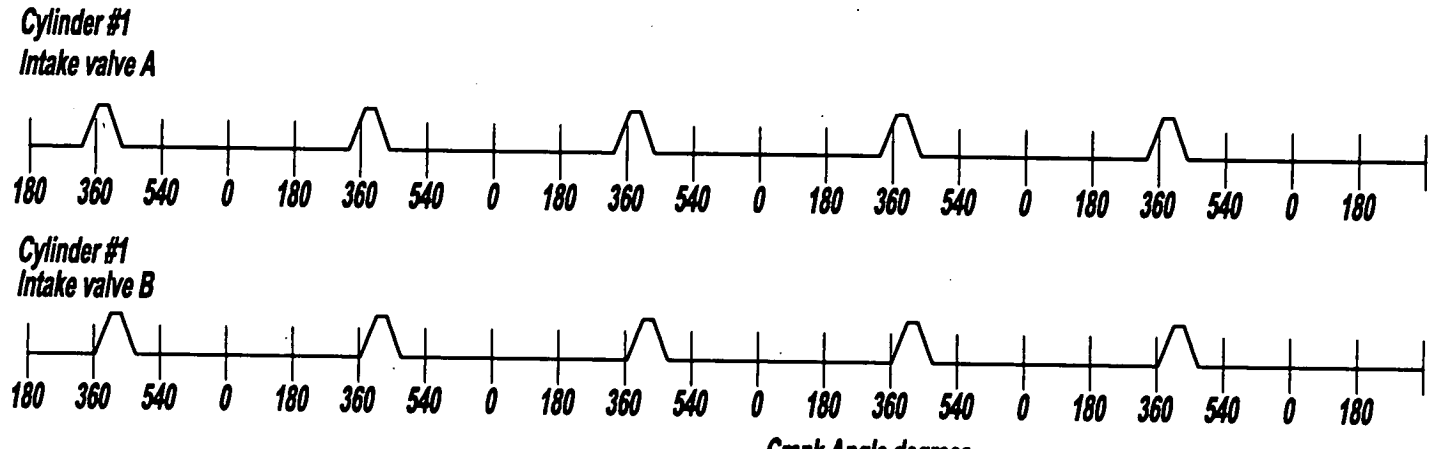
Cylinder #1
Intake valve A
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
Cylinder #1
Intake valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
Crank Angle degrees

FIG - 20

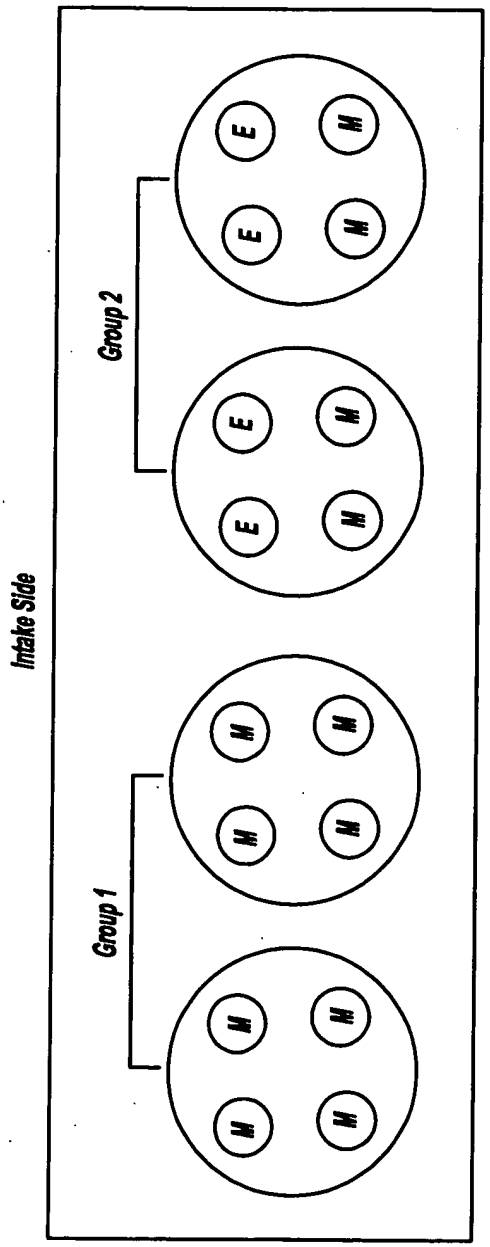

FIG - 21

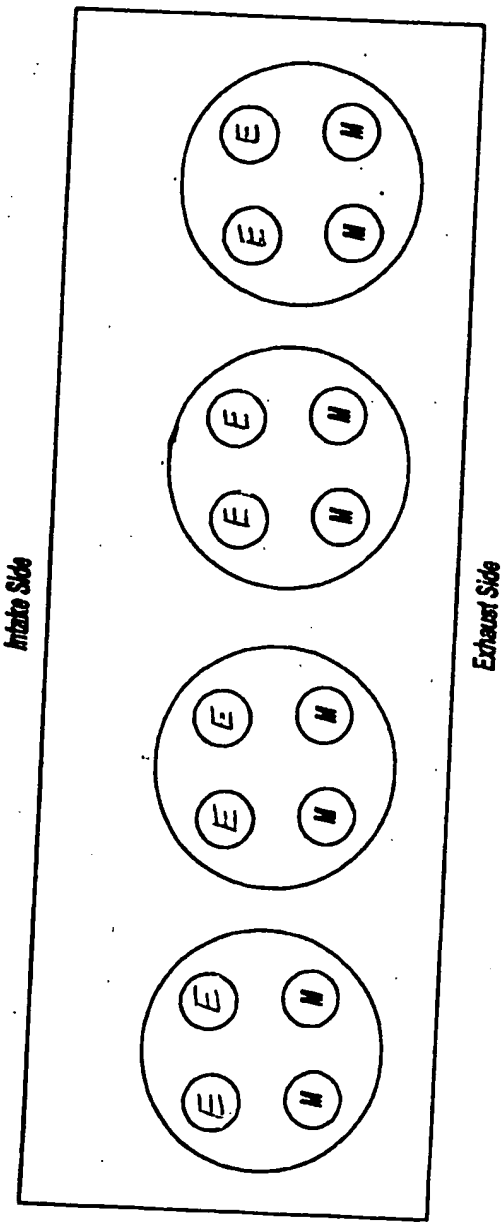

FIG - 21A

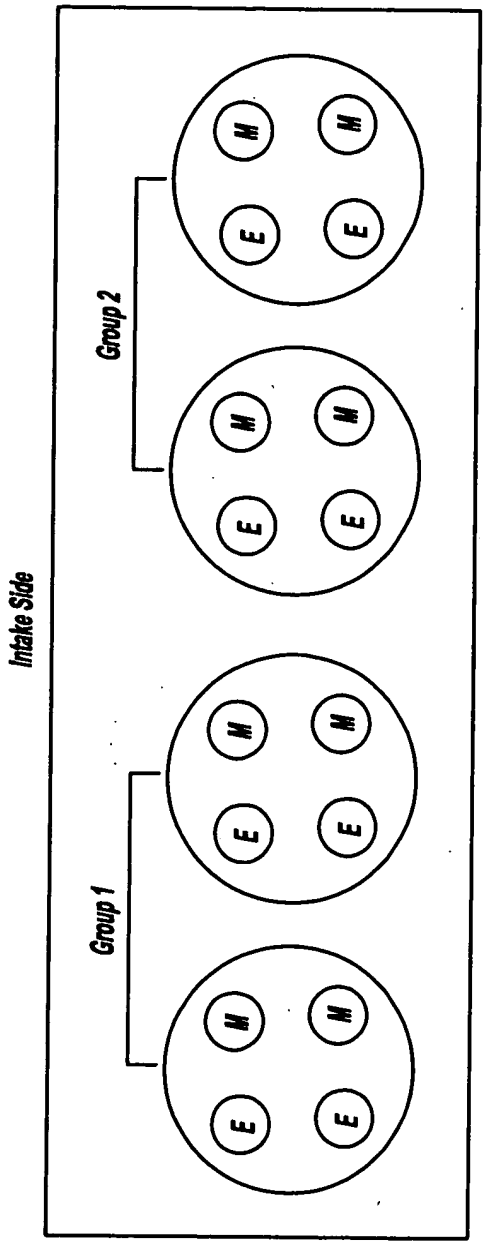
Intake Side
Exhaust Side
Group 1
Group 2
I
I
I
I
E
E
E
E
I
I
I
I
E
E
E
E
I
I
I
I
E
E
E
E

FIG - 22

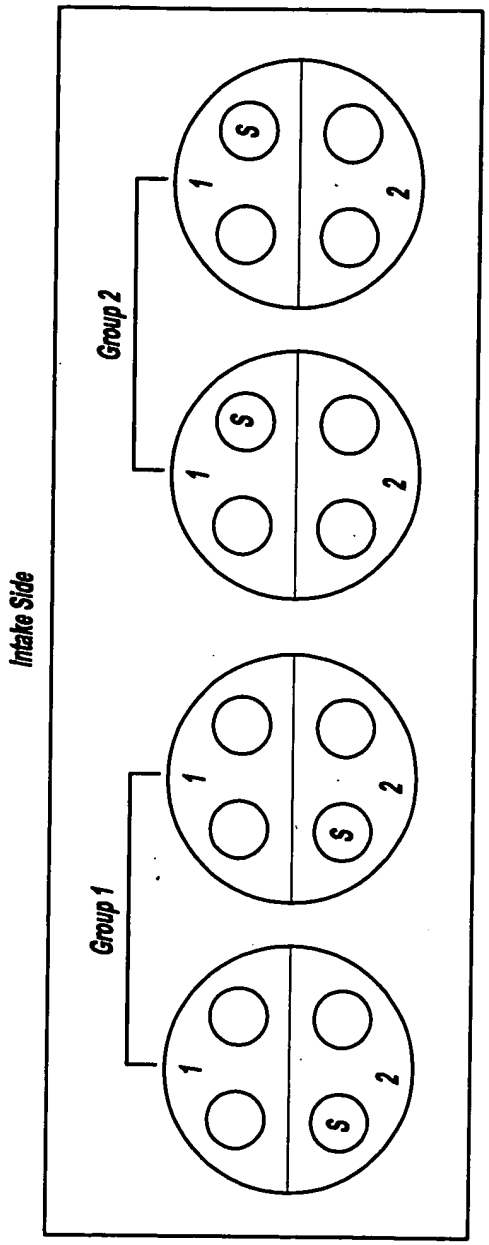

FIG - 23

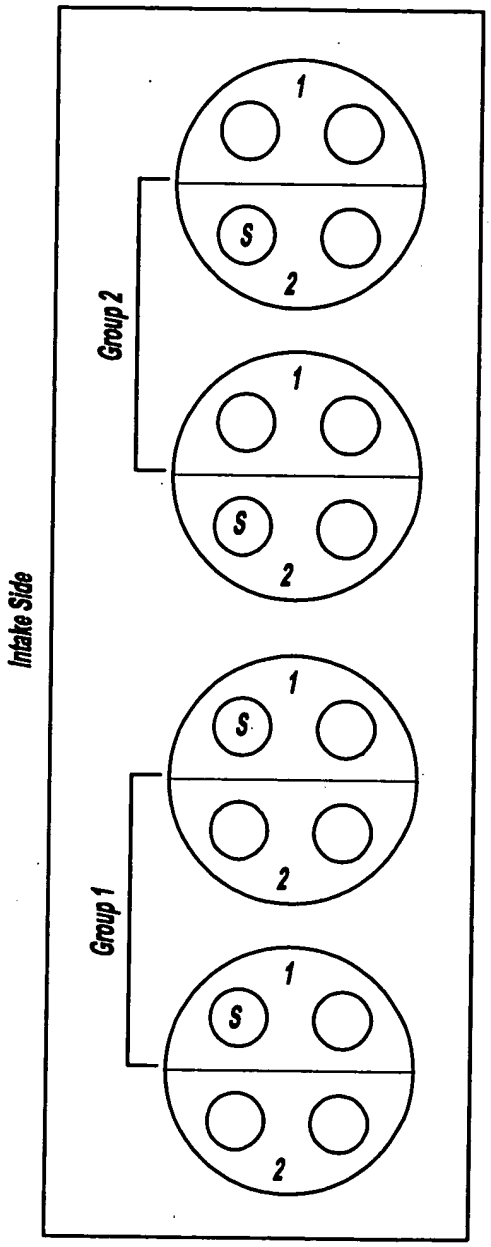

FIG - 24

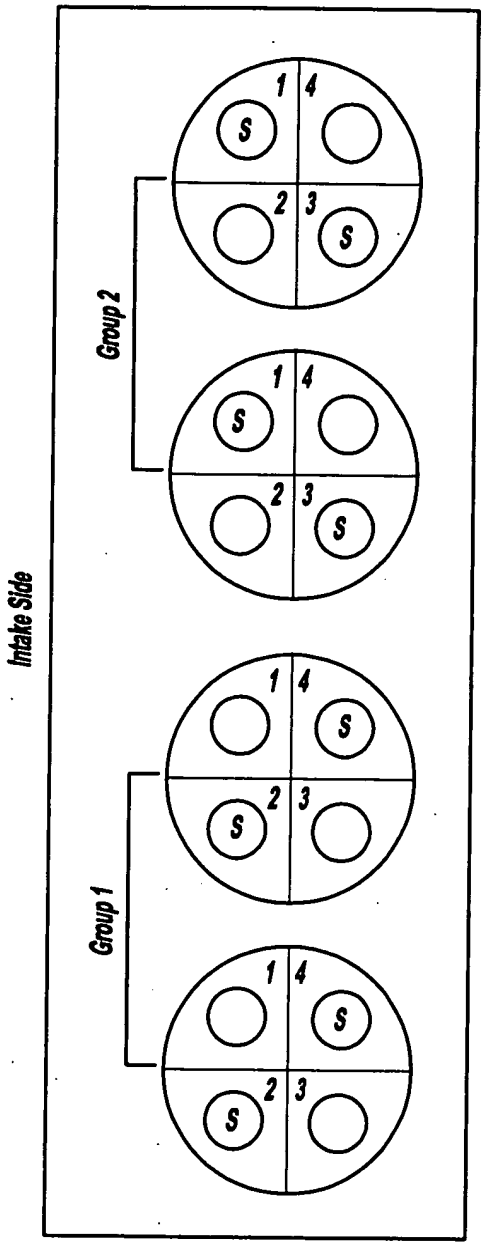

FIG - 25

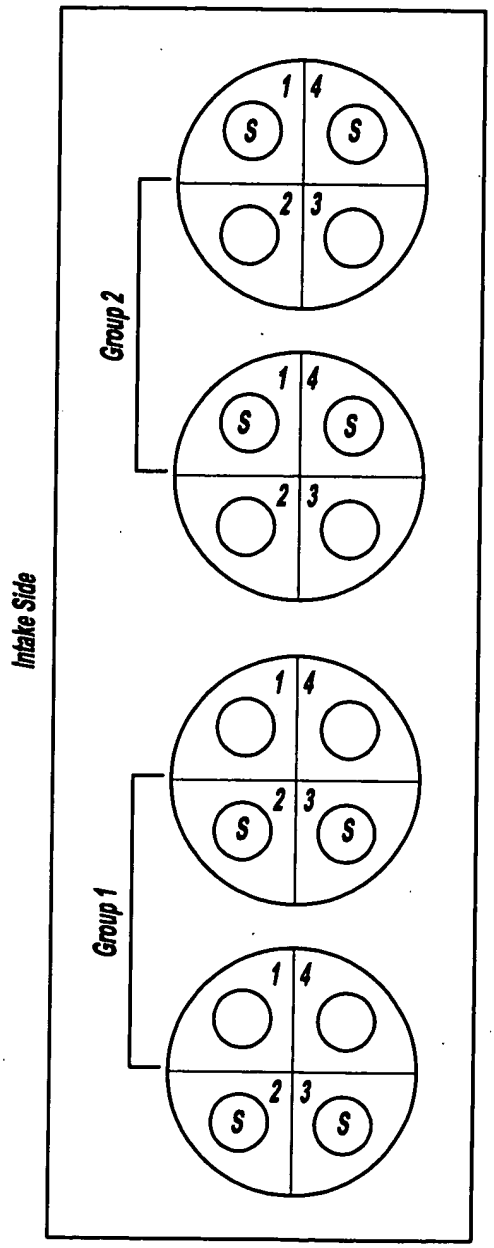

FIG - 26

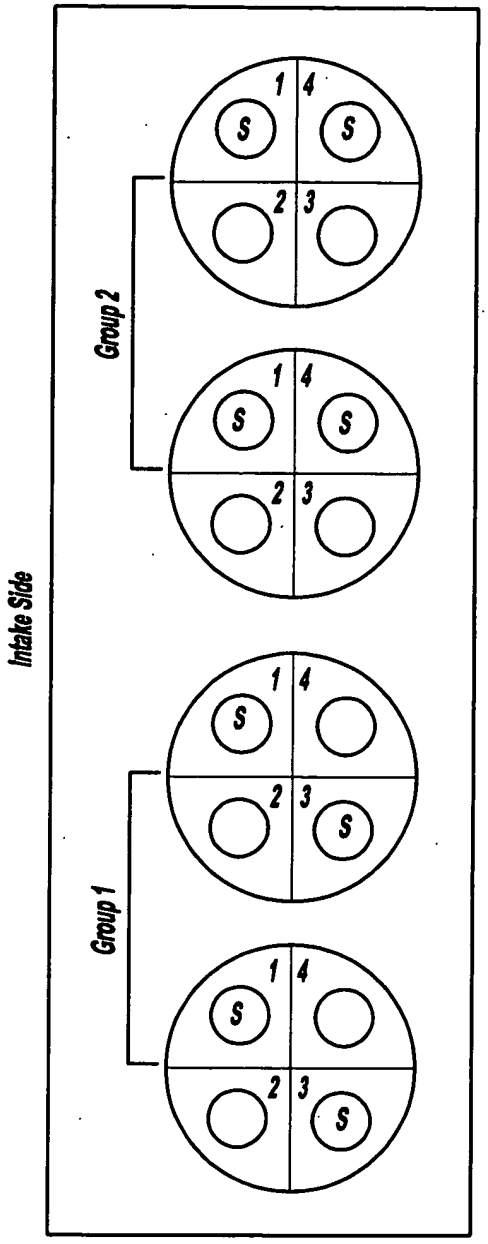

FIG - 27

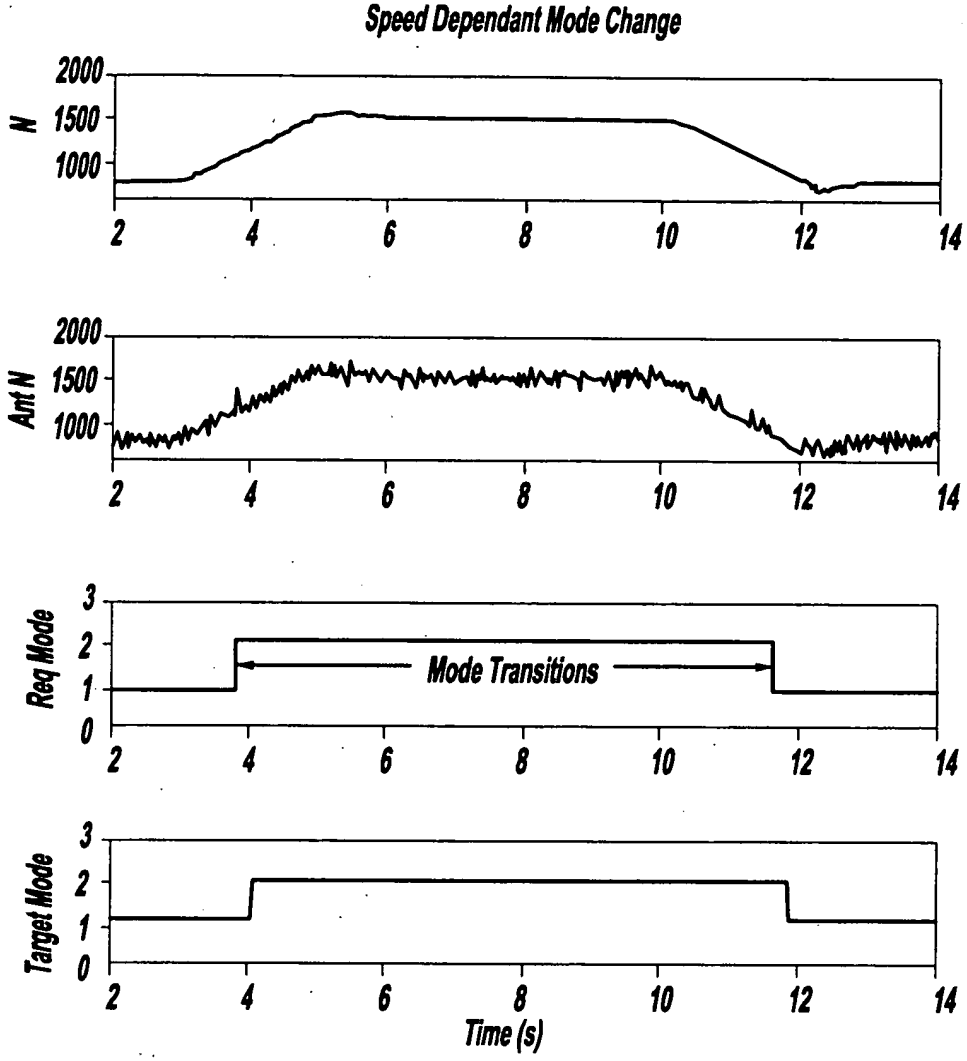
Speed Dependant Mode Change
N
2000
1500
1000
Ant N
2000
1500
1000
Req Mode
3
2
1
0
Mode Transitions
Target Mode
3
2
1
0
2
4
6
8
10
12
14
Time (s)

FIG - 28

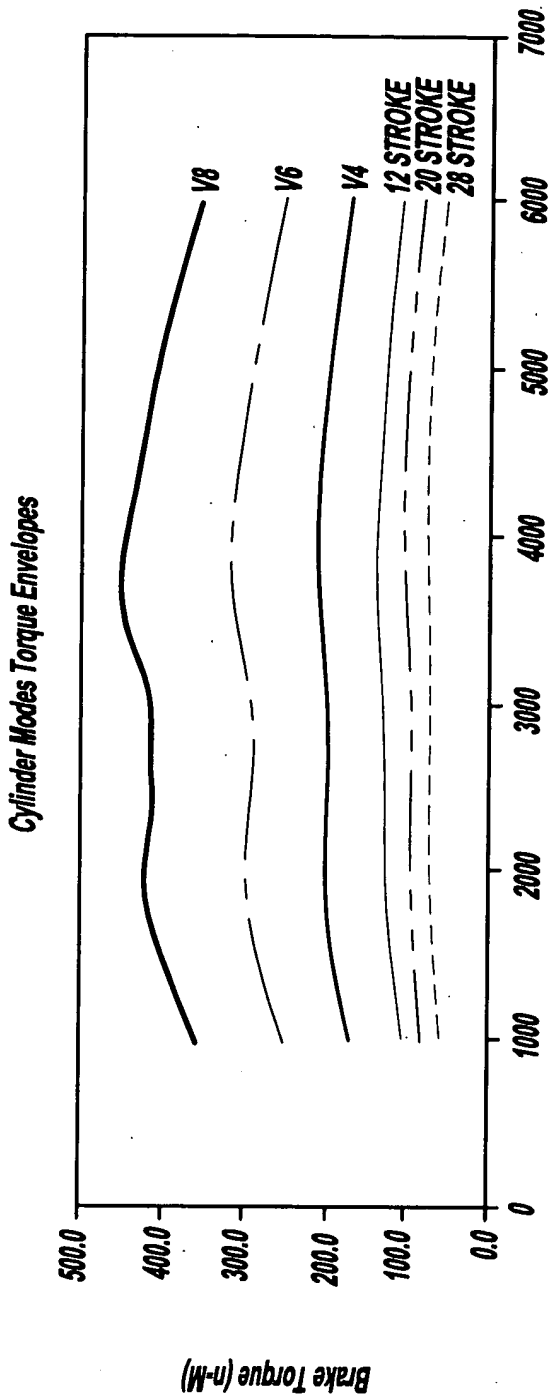
Cylinder Modes Torque Envelopes
V8
V6
V4
12 STROKE
20 STROKE
28 STROKE
500.0
400.0
300.0
200.0
100.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
Brake Torque (n-M)
Engine Speed

FIG - 29

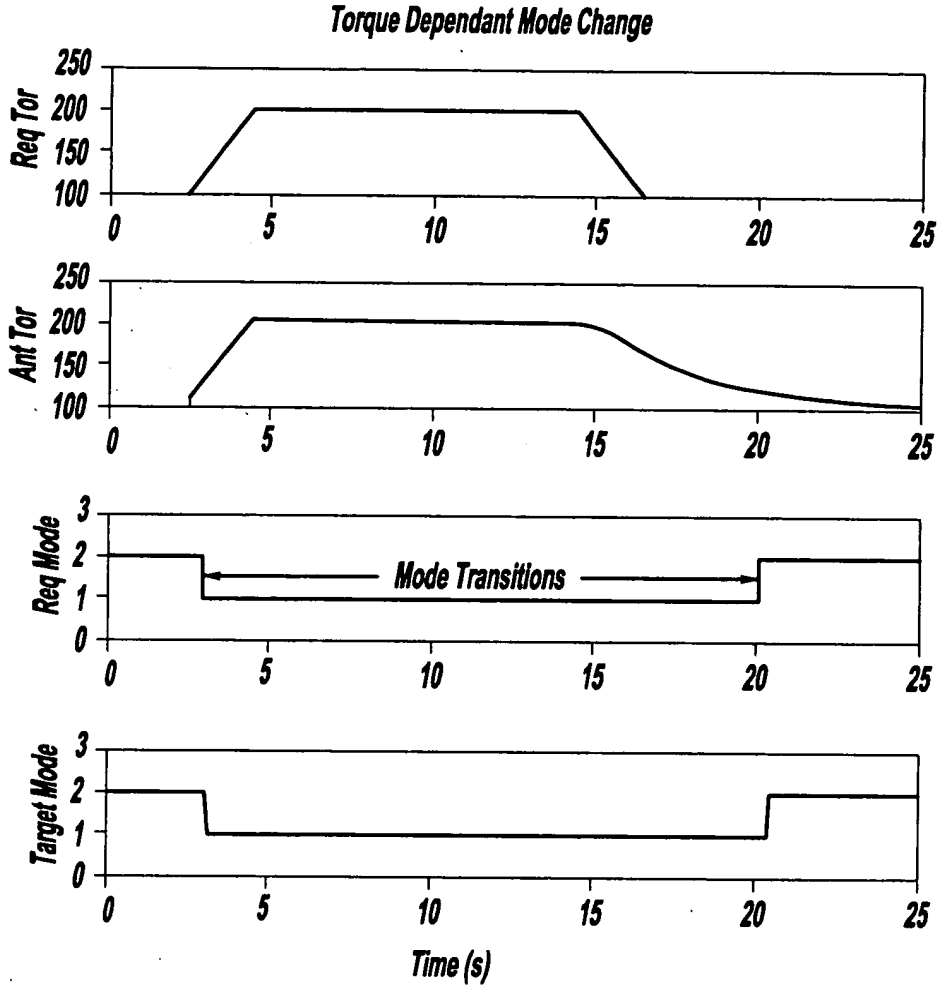
Torque Dependant Mode Change
Req Tor
Ant Tor
Req Mode
Mode Transitions
Target Mode
Time (s)
250
200
150
100
3
2
1
0
0
5
10
15
20
25

FIG - 30

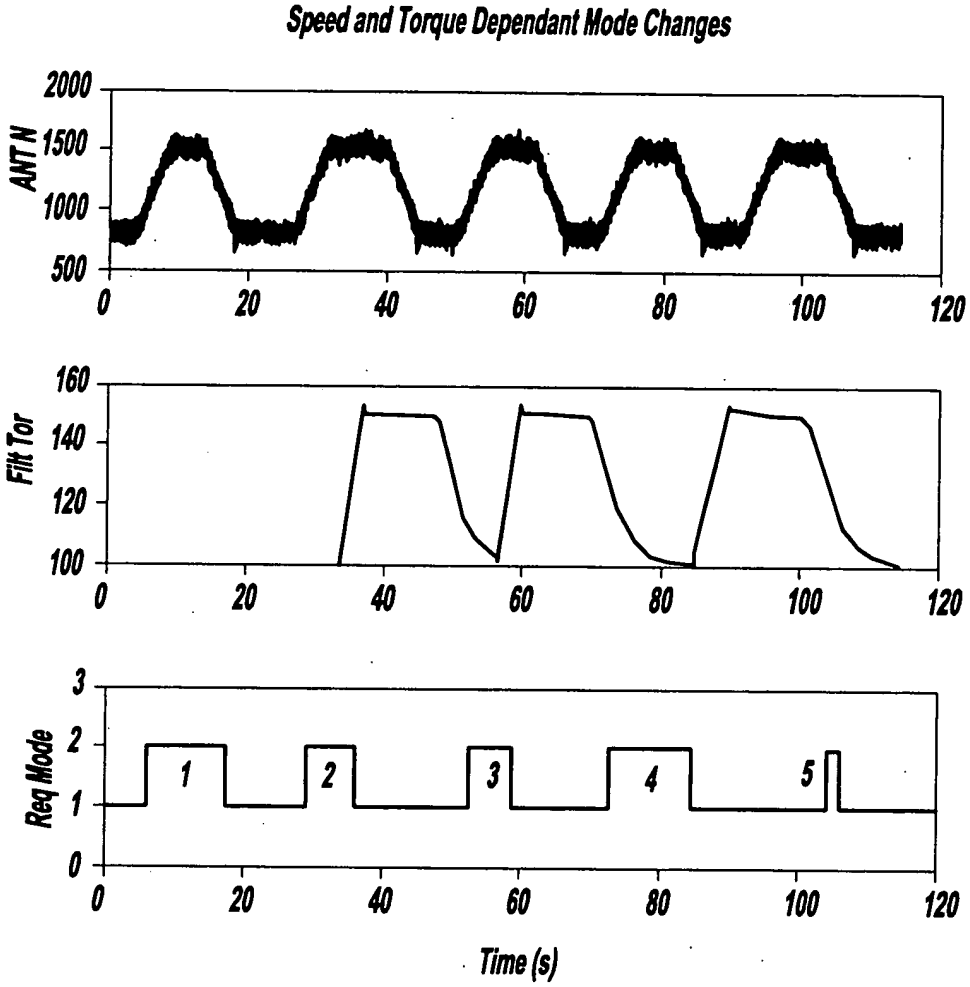
Speed and Torque Dependant Mode Changes
ANT N
2000
1500
1000
500
0
20
40
60
80
100
120
Filt Tor
160
140
120
100
Req Mode
3
2
1
0
1
2
3
4
5
Time (s)

FIG - 31

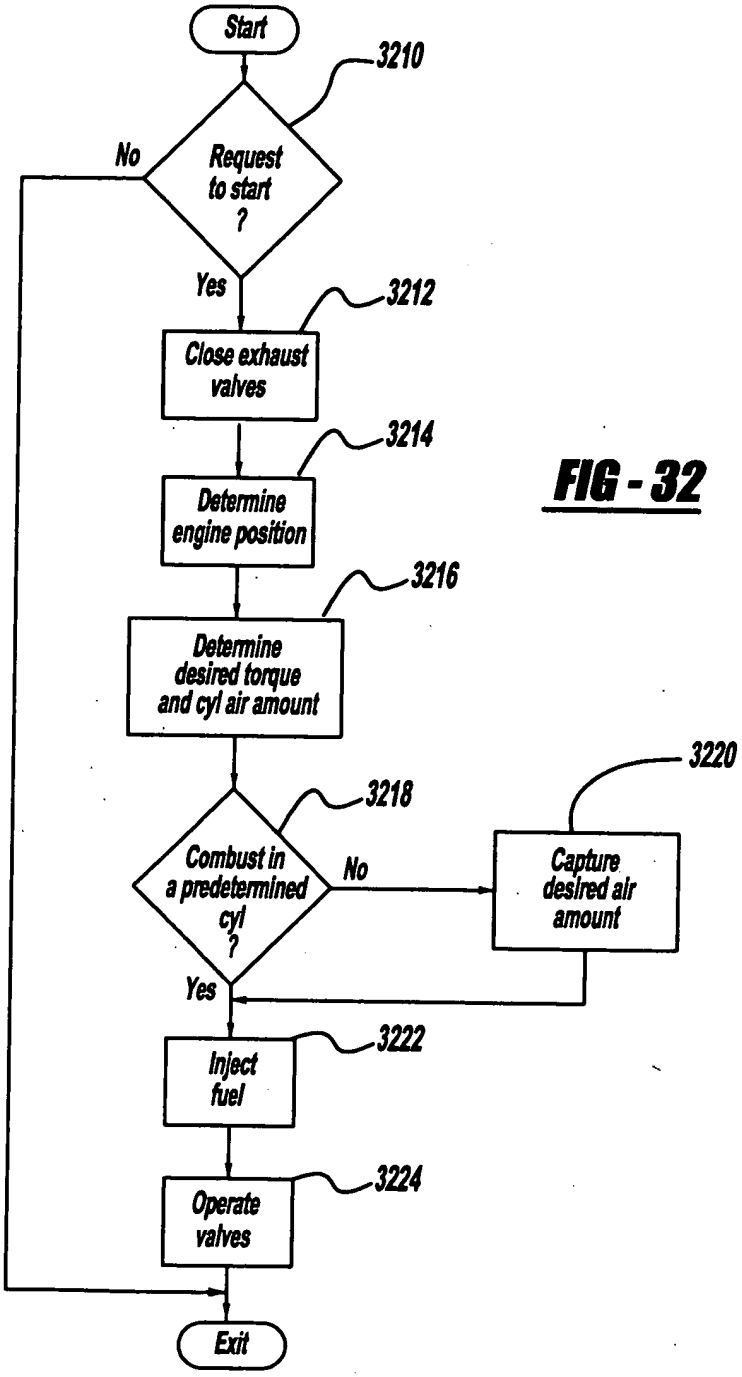
Start
3210
Request to start ?
No
Yes
3212
Close exhaust valves
3214
Determine engine position
3216
Determine desired torque and cyl air amount
3218
Combust in a predetermined cyl ?
No
3220
Capture desired air amount
Yes
3222
Inject fuel
3224
Operate valves
Exit

FIG - 32

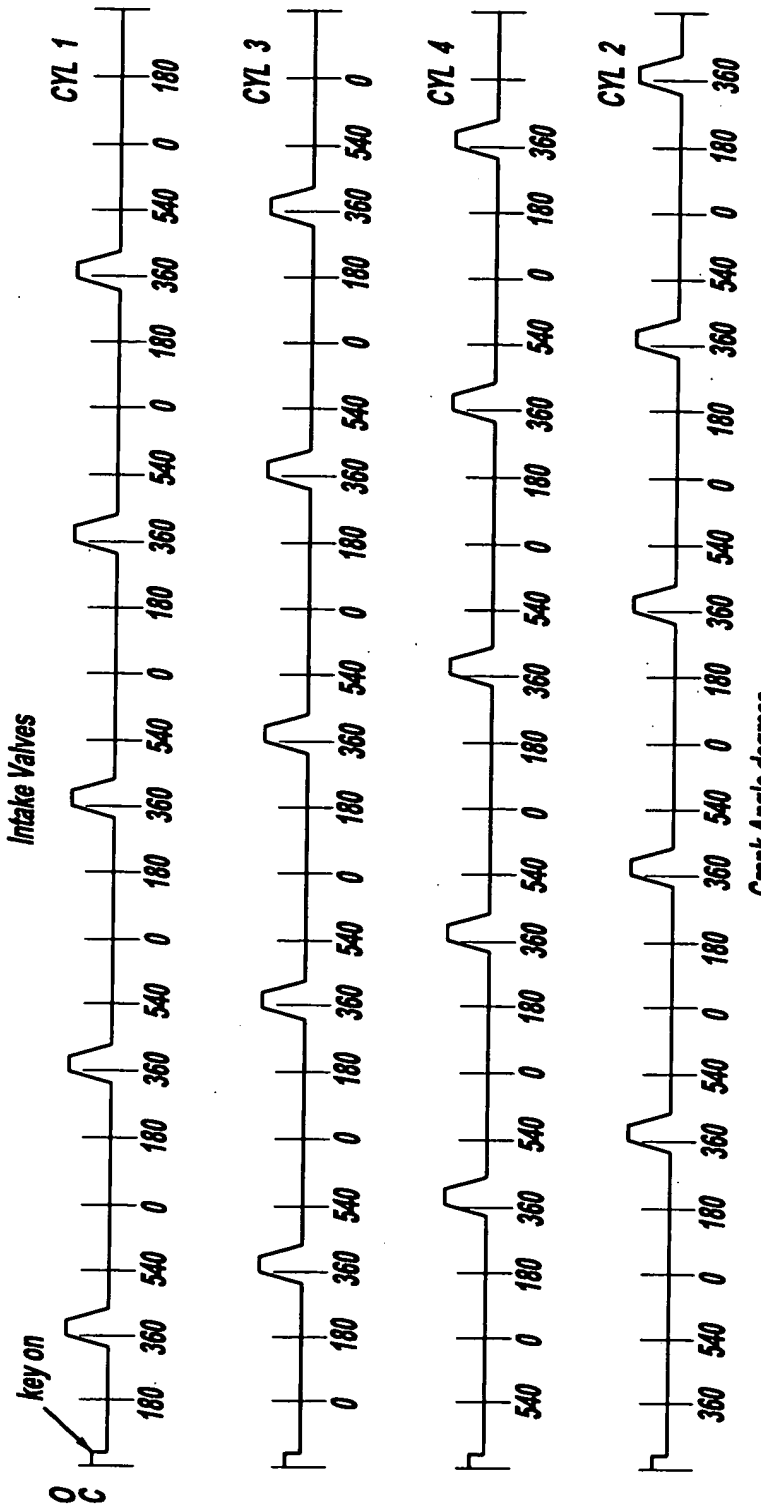
Intake Valves
key on
O
C
CYL 1
CYL 3
CYL 4
CYL 2
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 33a

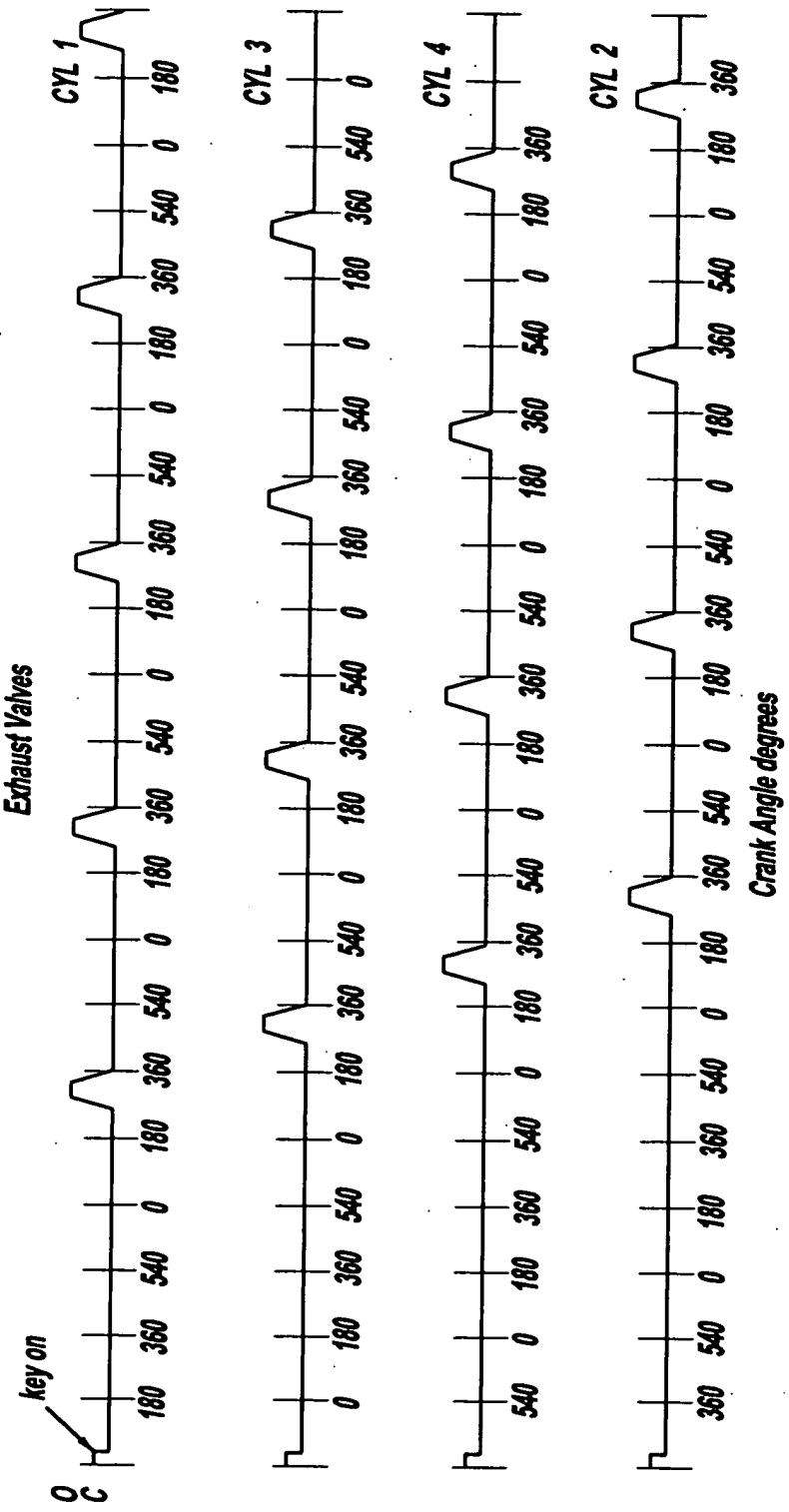
Exhaust Valves
CYL 1
CYL 3
CYL 4
CYL 2
key on
O
C
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 33b

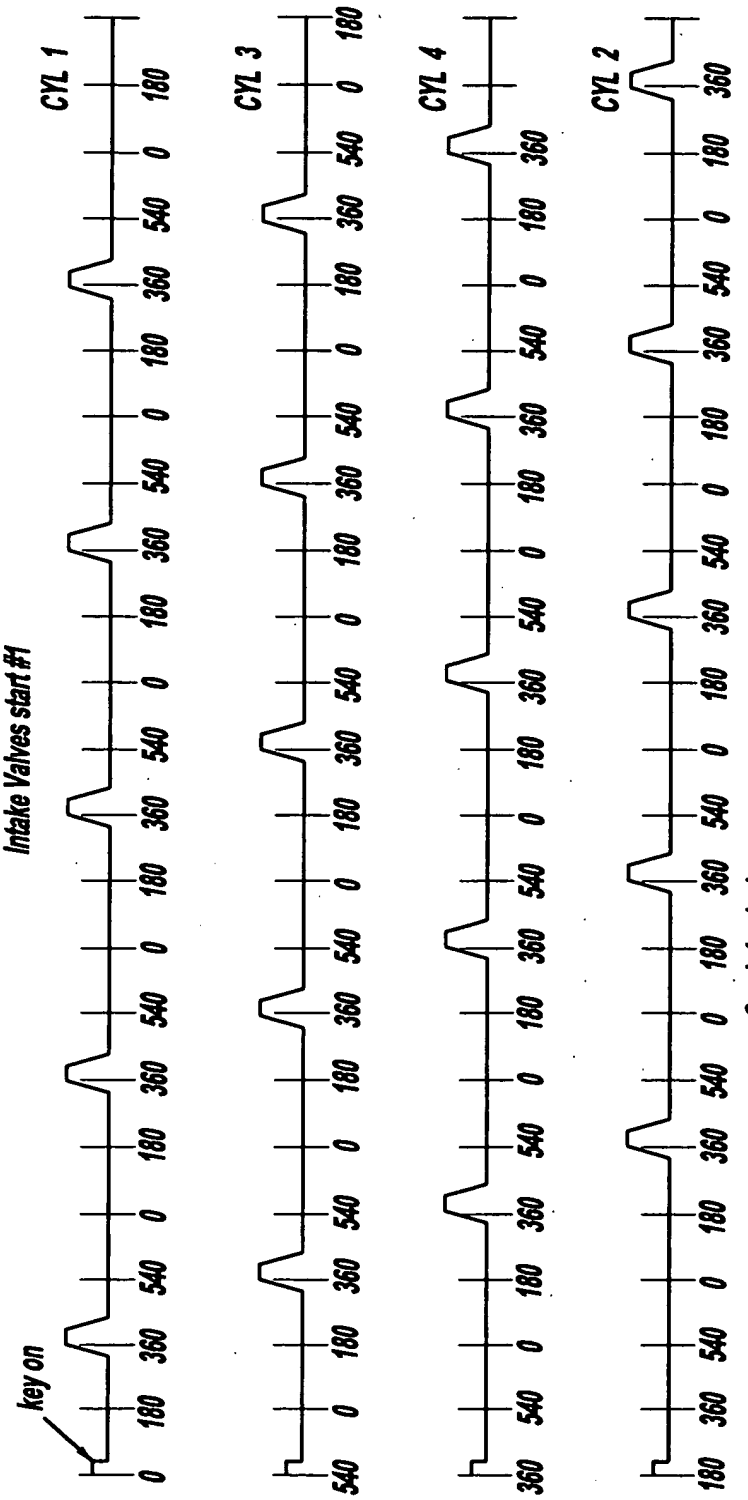
Intake Valves start #1
key on
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 34a

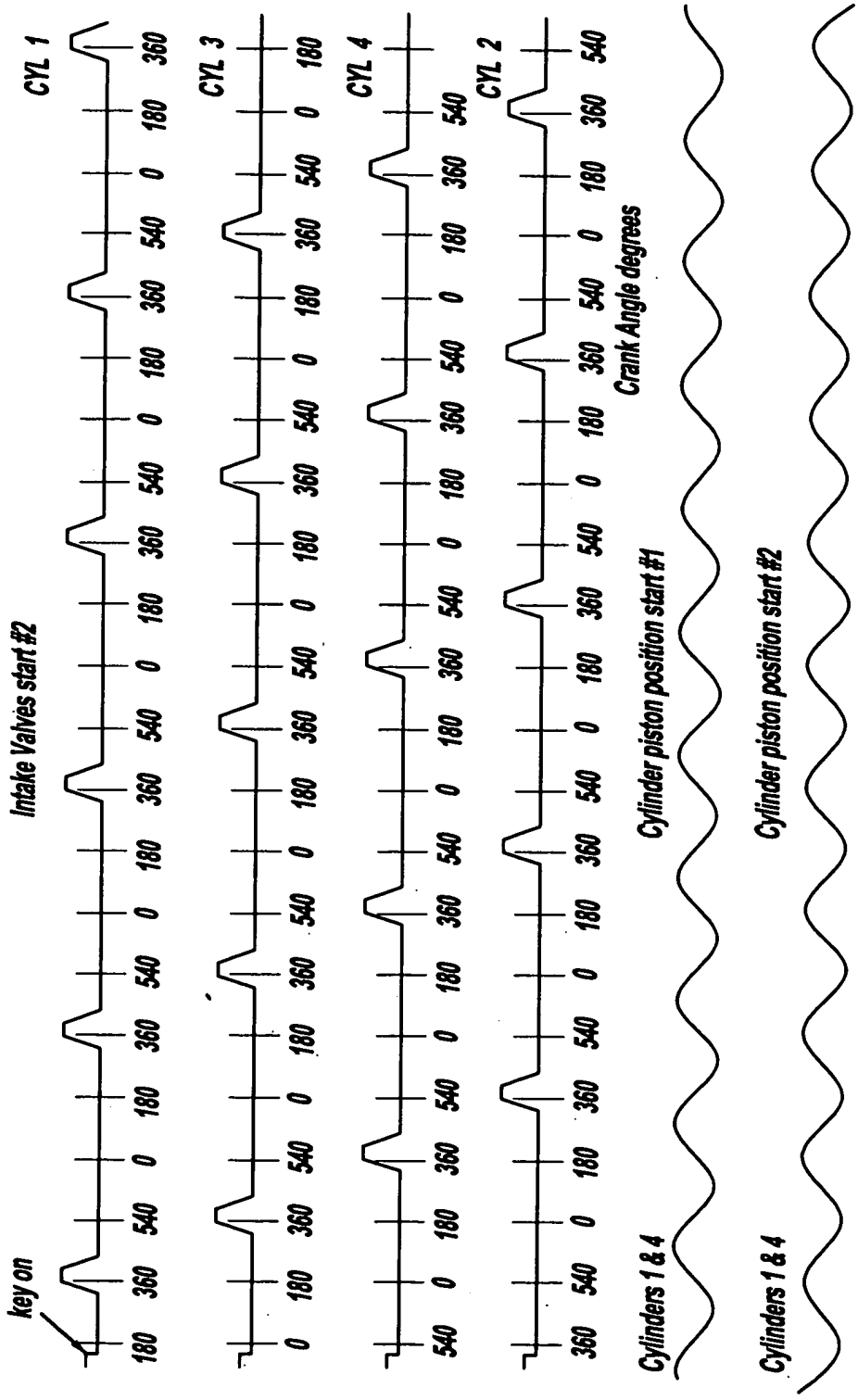
key on
Intake Valves start #2
CYL 1
CYL 3
CYL 4
CYL 2
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540
Crank Angle degrees
Cylinders 1 & 4
Cylinder piston position start #1
Cylinders 1 & 4
Cylinder piston position start #2

FIG - 34b

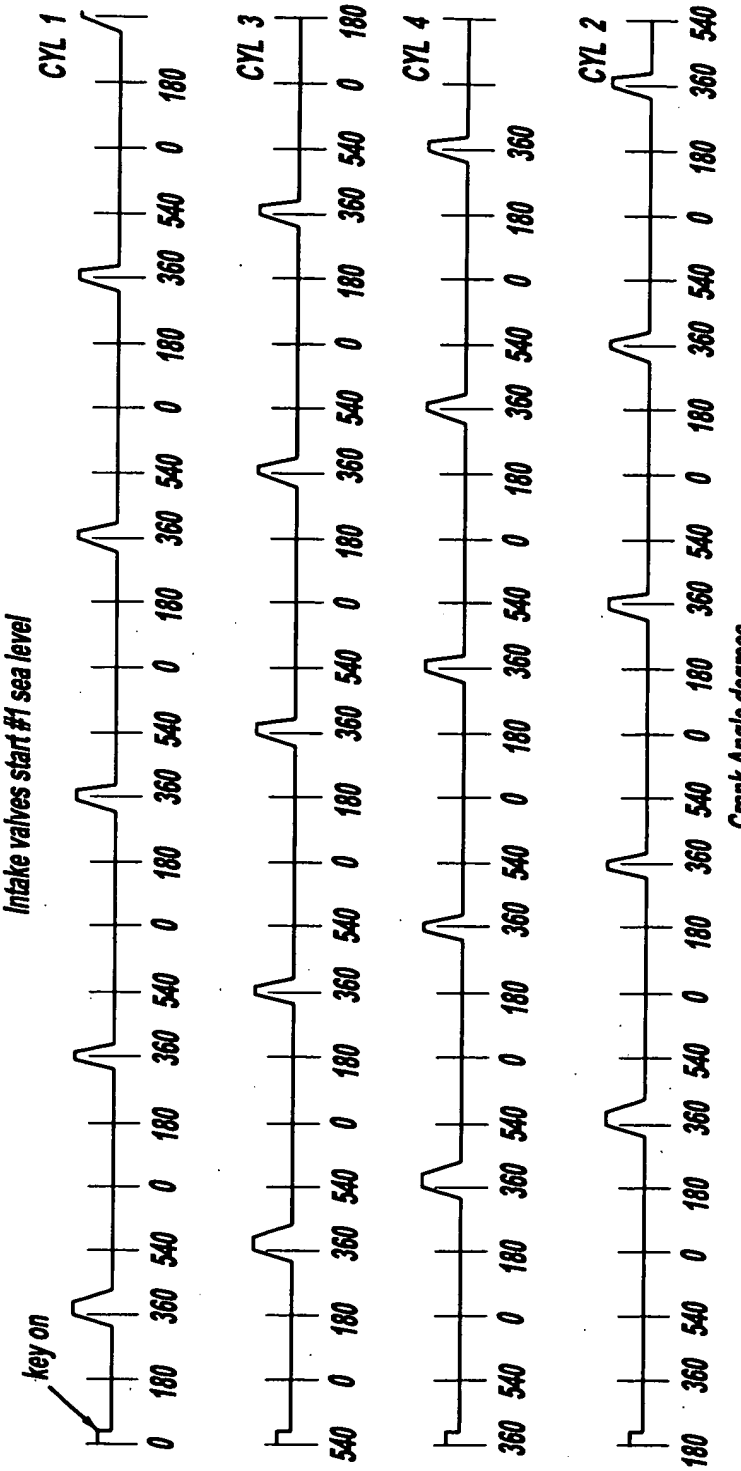
Intake valves start #1 sea level
key on
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 35a

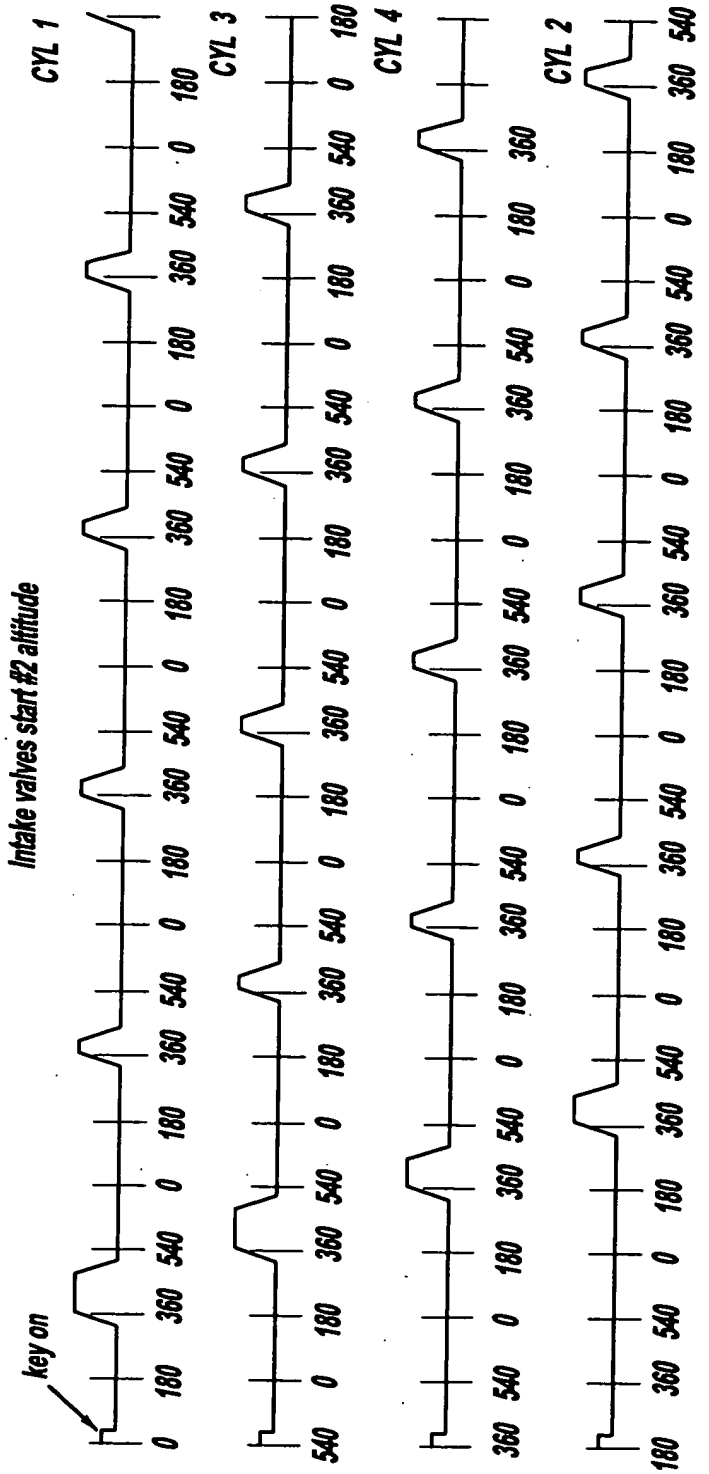
Intake valves start #2 altitude
key on
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360

FIG - 35b

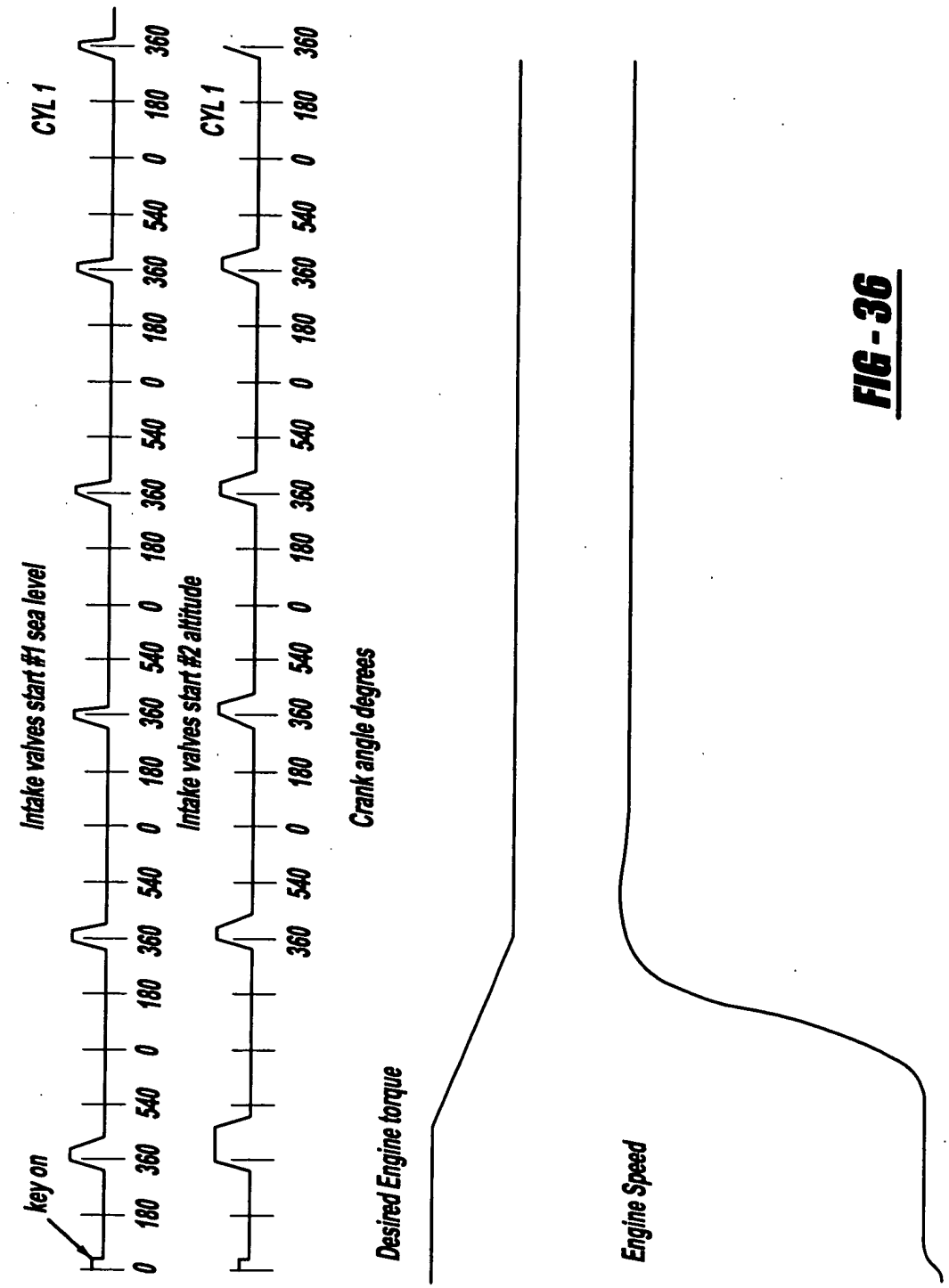
key on
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Intake valves start #1 sea level
CYL 1
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Intake valves start #2 altitude
CYL 1
Crank angle degrees
Desired Engine torque
Engine Speed

FIG - 36

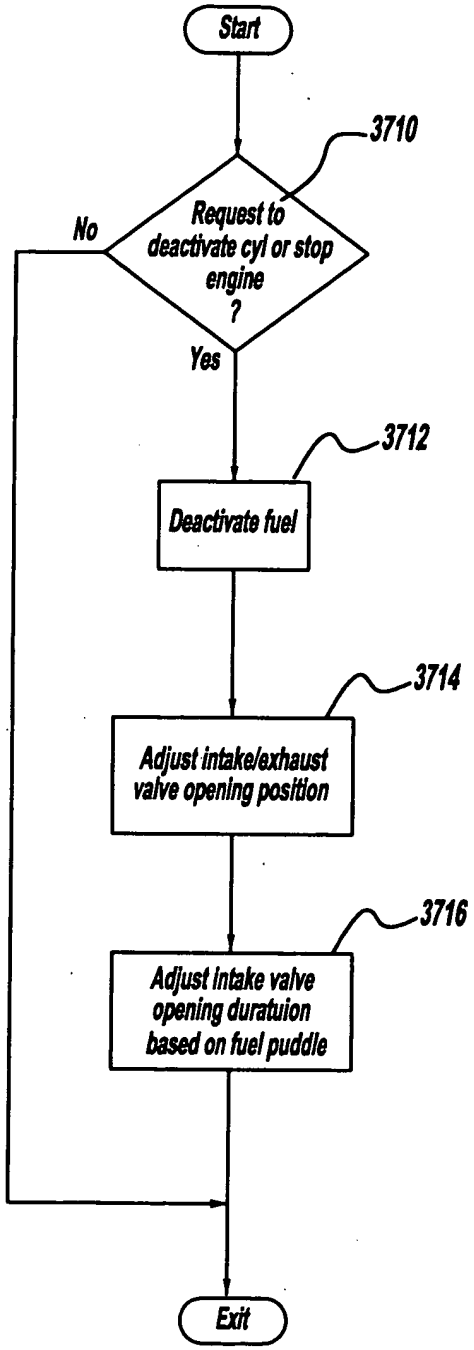
Start
3710
Request to deactivate cyl or stop engine ?
No
Yes
3712
Deactivate fuel
3714
Adjust intake/exhaust valve opening position
3716
Adjust intake valve opening duratuion based on fuel puddle
Exit

FIG - 37

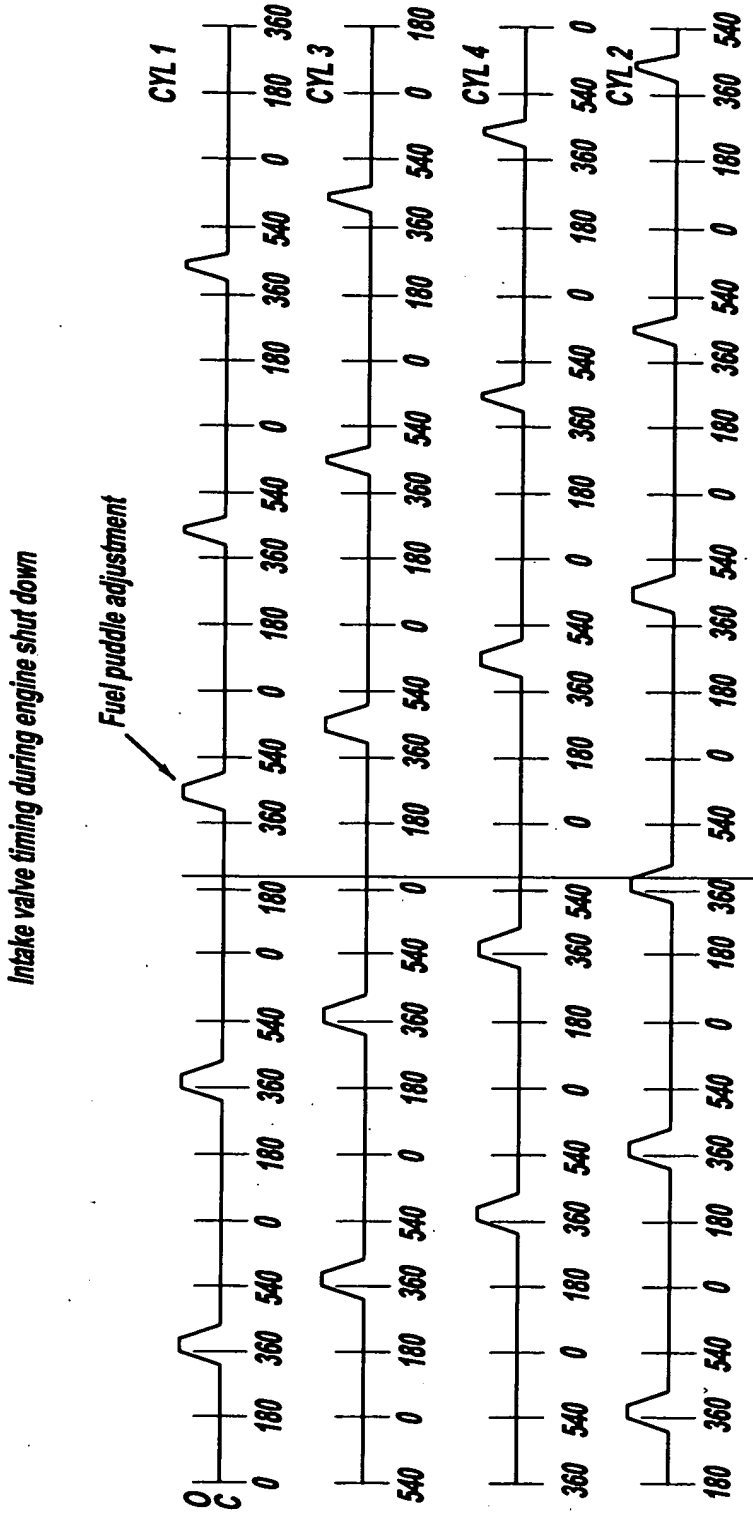
Intake valve timing during engine shut down
Fuel puddle adjustment
CYL 1
CYL 3
CYL 4
CYL 2
O
C
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Shut down request

FIG - 38

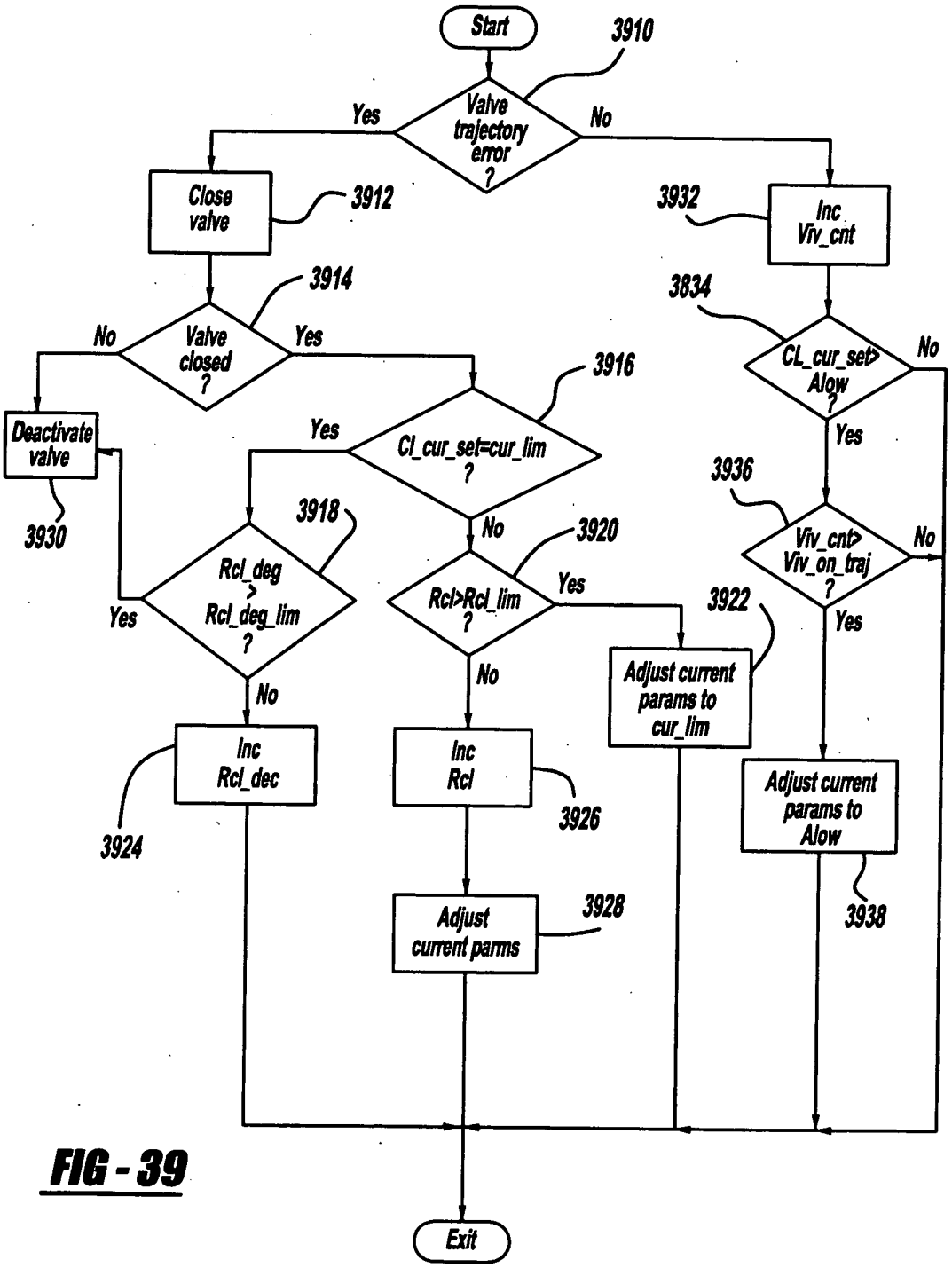
Start
3910
Valve trajectory error ?
Yes
No
Close valve
3912
3932
Inc Viv_cnt
3914
3834
Valve closed ?
No
Yes
CL_cur_set> Alow ?
No
Yes
3916
Deactivate valve
Yes
Cl_cur_set=cur_lim ?
3936
3930
3918
No
3920
Viv_cnt> Viv_on_traj ?
No
Rcl_deg > Rcl_deg_lim ?
Yes
Rcl>Rcl_lim ?
Yes
3922
Yes
No
Adjust current params to cur_lim
No
Inc Rcl_dec
Inc Rcl
Adjust current params to Alow
3924
3926
3938
Adjust current parms
3928
Exit

FIG - 39

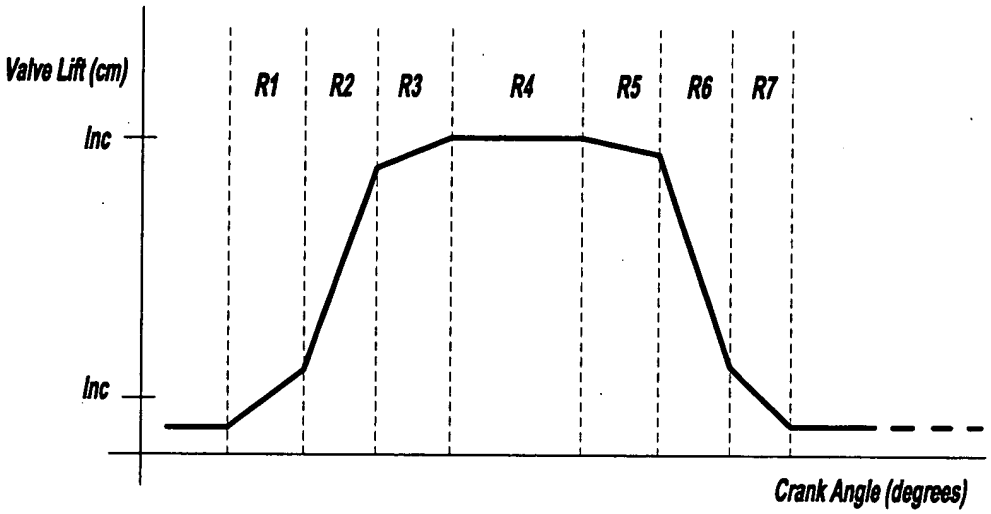

FIG - 40

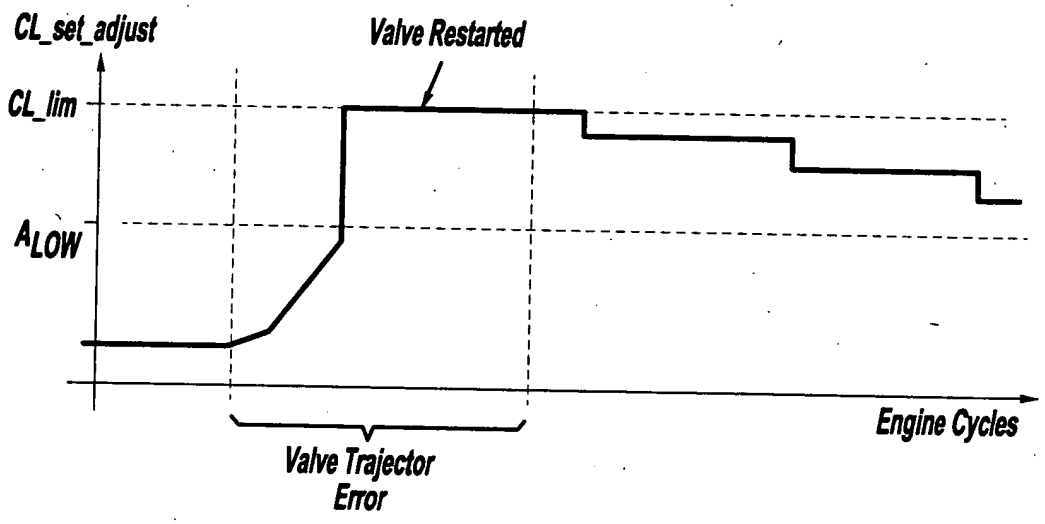
CL_set_adjust
Valve Restarted
CL_lim
A_{LOW}
Engine Cycles
Valve Trajector
Error

FIG - 41

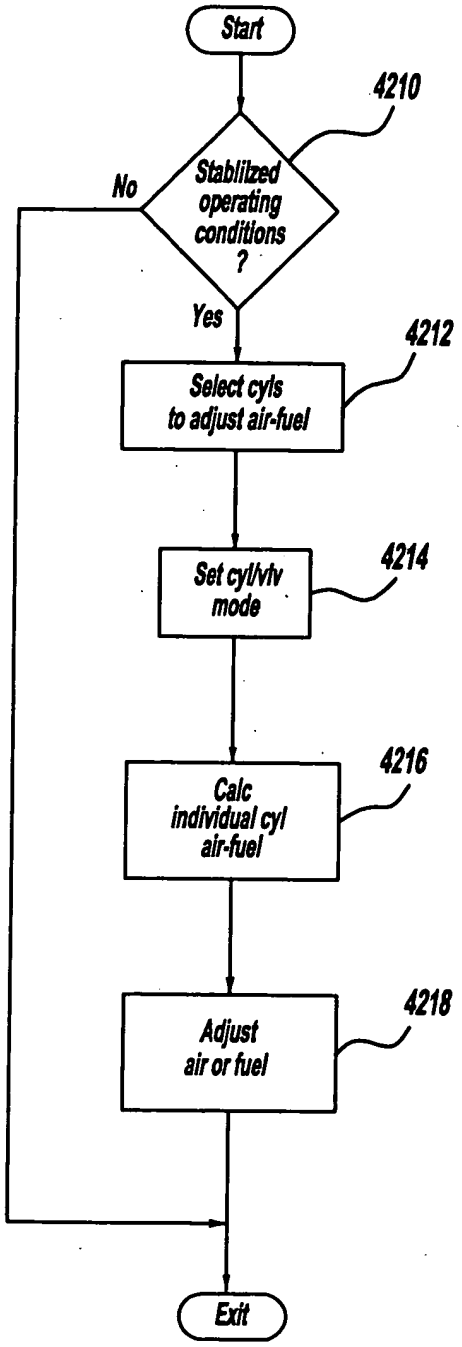
Start
4210
Stablilzed operating conditions ?
No
Yes
4212
Select cyls to adjust air-fuel
4214
Set cyl/vlv mode
4216
Calc individual cyl air-fuel
4218
Adjust air or fuel
Exit

FIG - 42

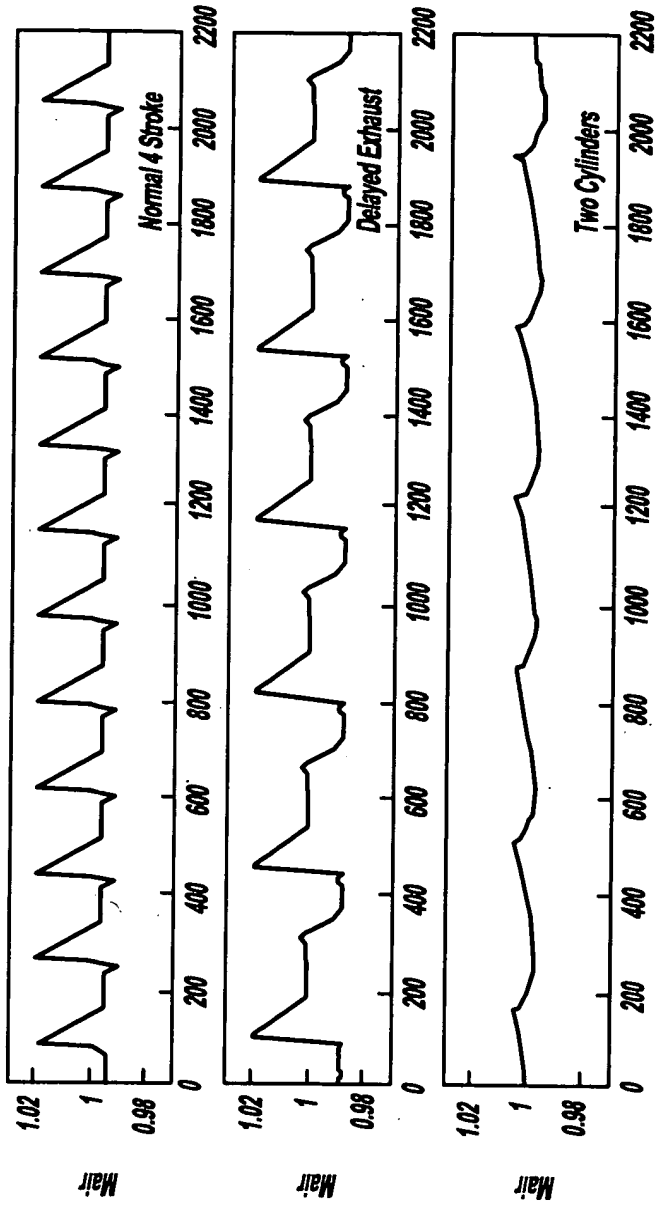
Normal 4 Stroke
Delayed Exhaust
Two Cylinders
Mair
1.02
1
0.98
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

FIG - 43

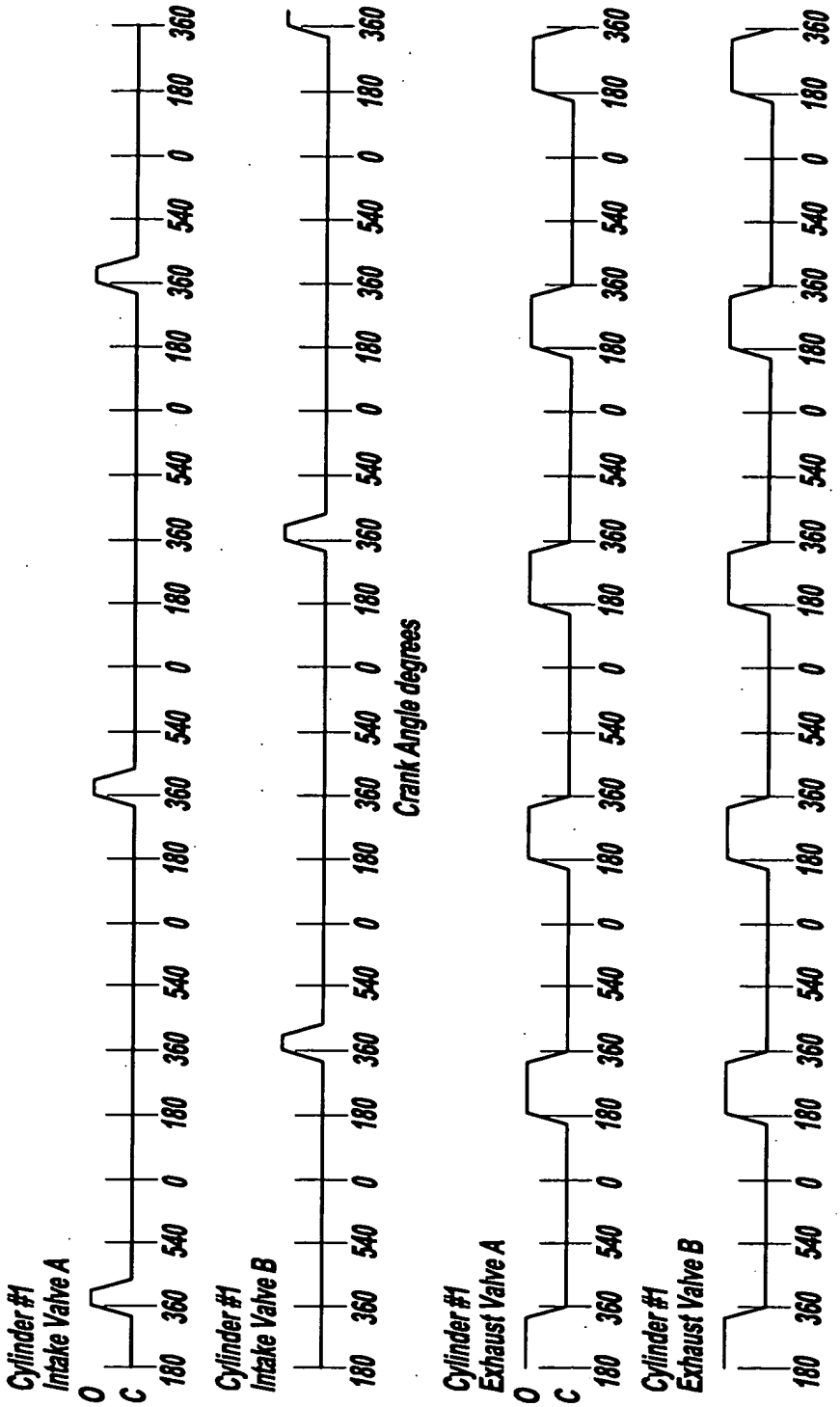
Cylinder #1
Intake Valve A
O
C
Cylinder #1
Intake Valve B
Cylinder #1
Exhaust Valve A
Cylinder #1
Exhaust Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 44

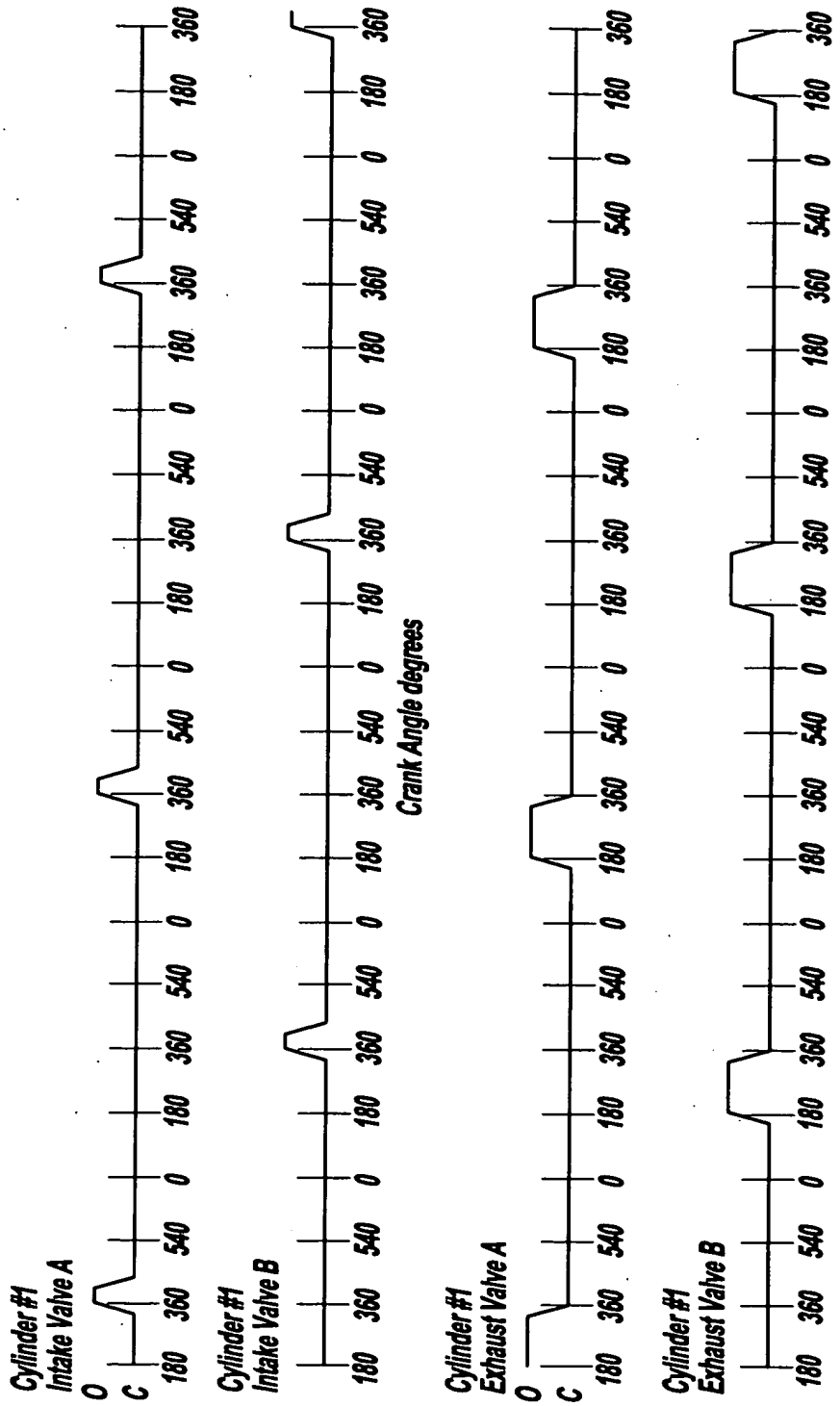
Cylinder #1
Intake Valve A
O
C
Cylinder #1
Intake Valve B
Cylinder #1
Exhaust Valve A
Cylinder #1
Exhaust Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 45

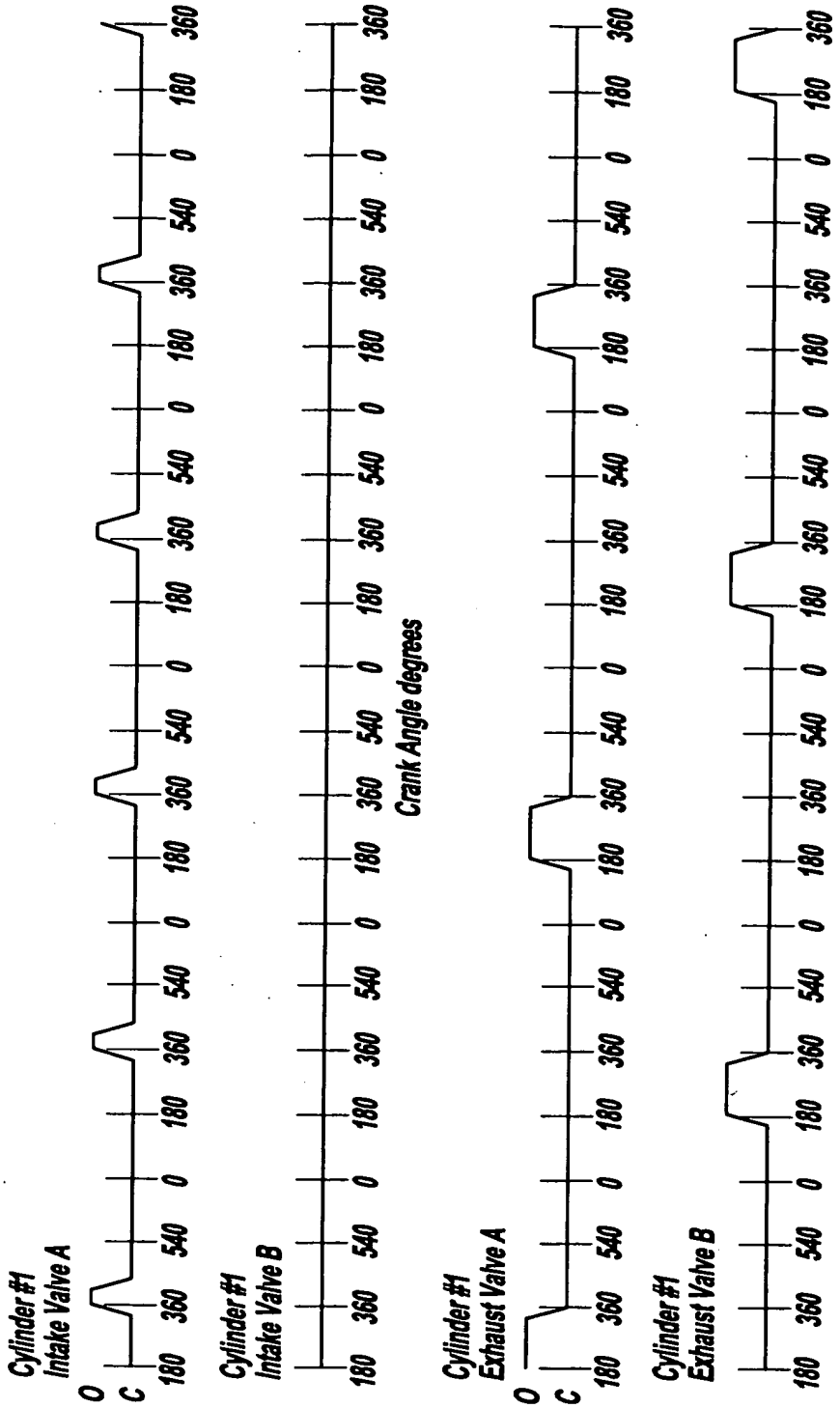
Cylinder #1
Intake Valve A
O
C
Cylinder #1
Intake Valve B
Cylinder #1
Exhaust Valve A
Cylinder #1
Exhaust Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 46

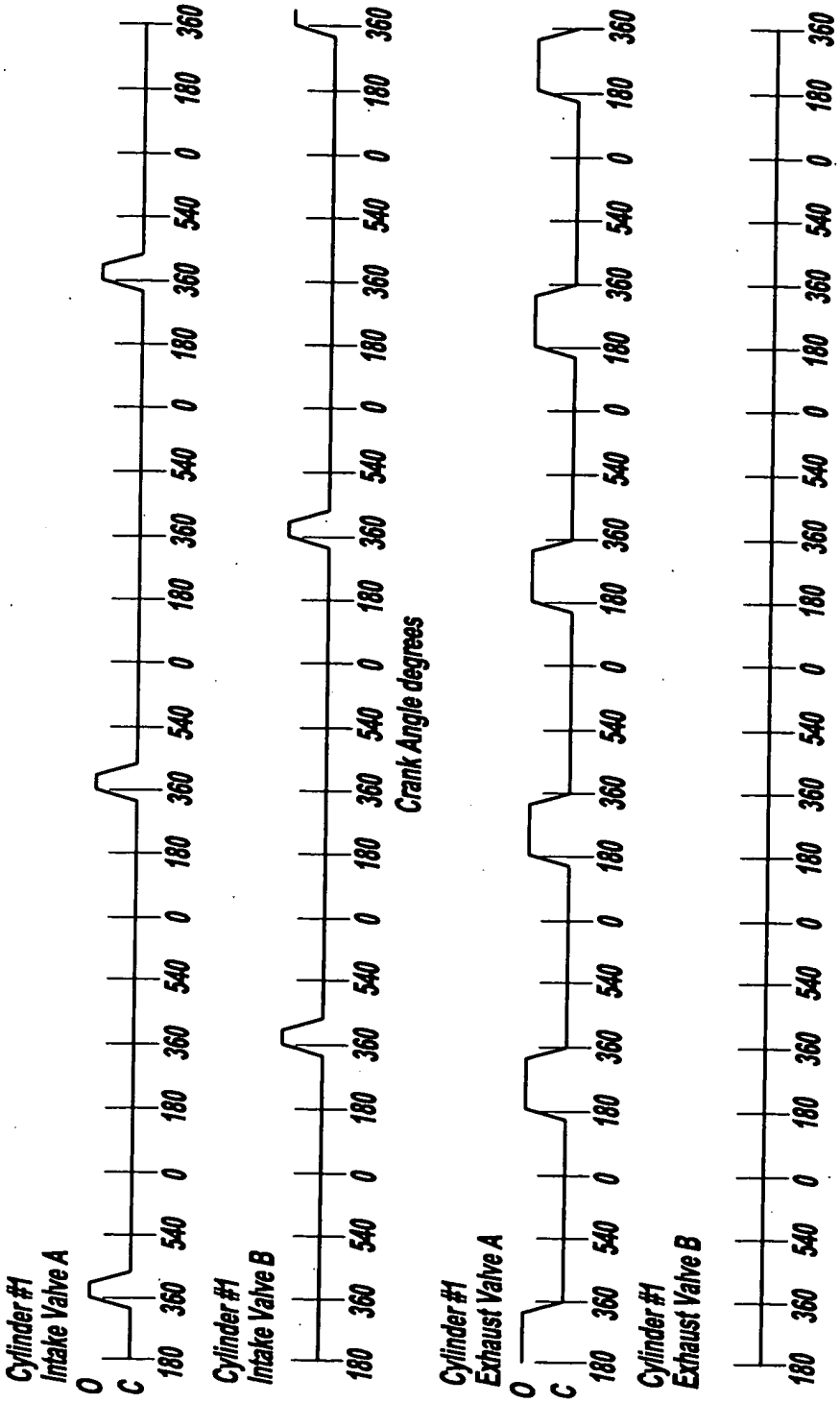
Cylinder #1
Intake Valve A
O
C
Cylinder #1
Intake Valve B
Cylinder #1
Exhaust Valve A
Cylinder #1
Exhaust Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees

FIG - 47

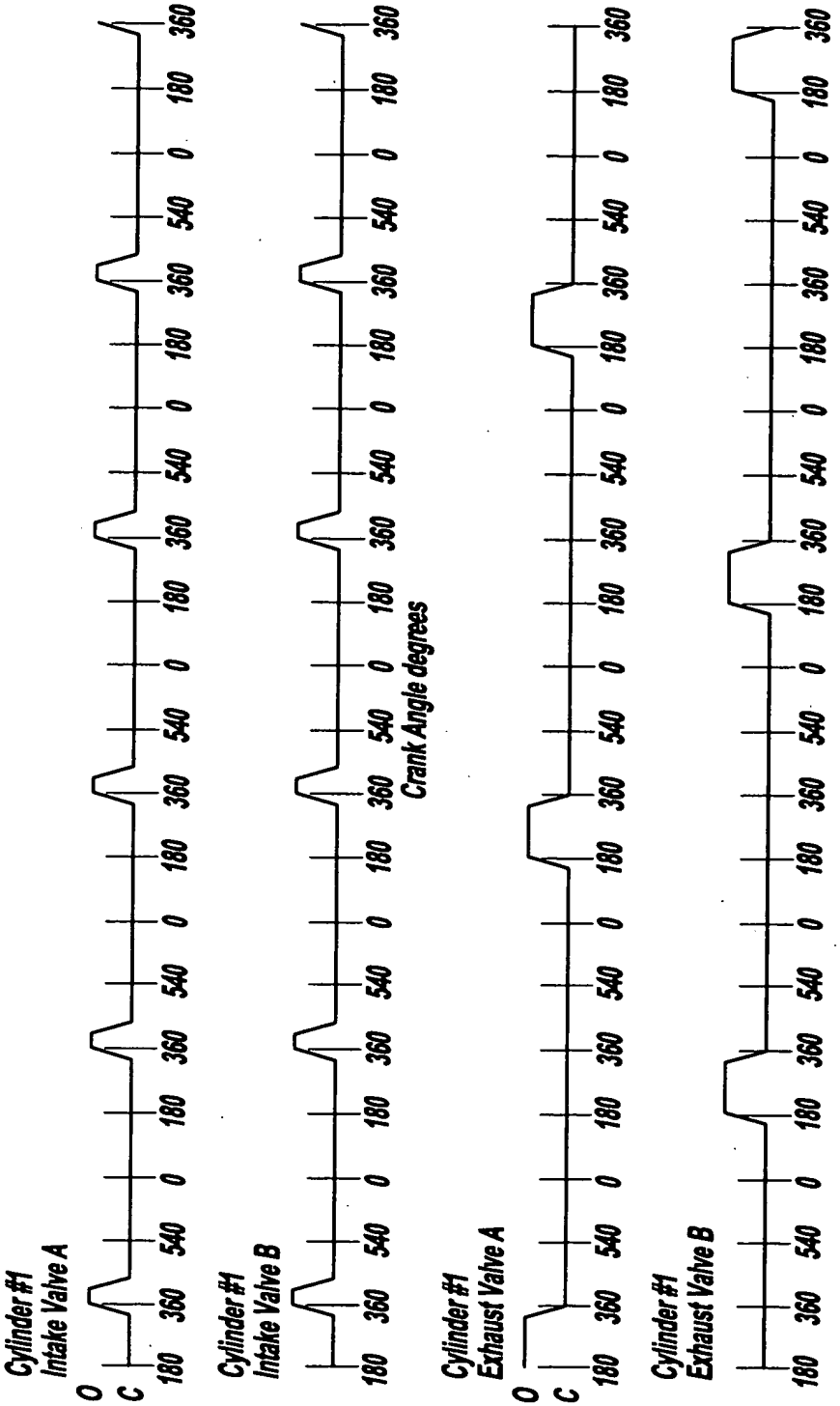
Cylinder #1
Intake Valve A
O
C
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Cylinder #1
Intake Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Cylinder #1
Exhaust Valve A
O
C
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Cylinder #1
Exhaust Valve B
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Crank Angle degrees

FIG - 48

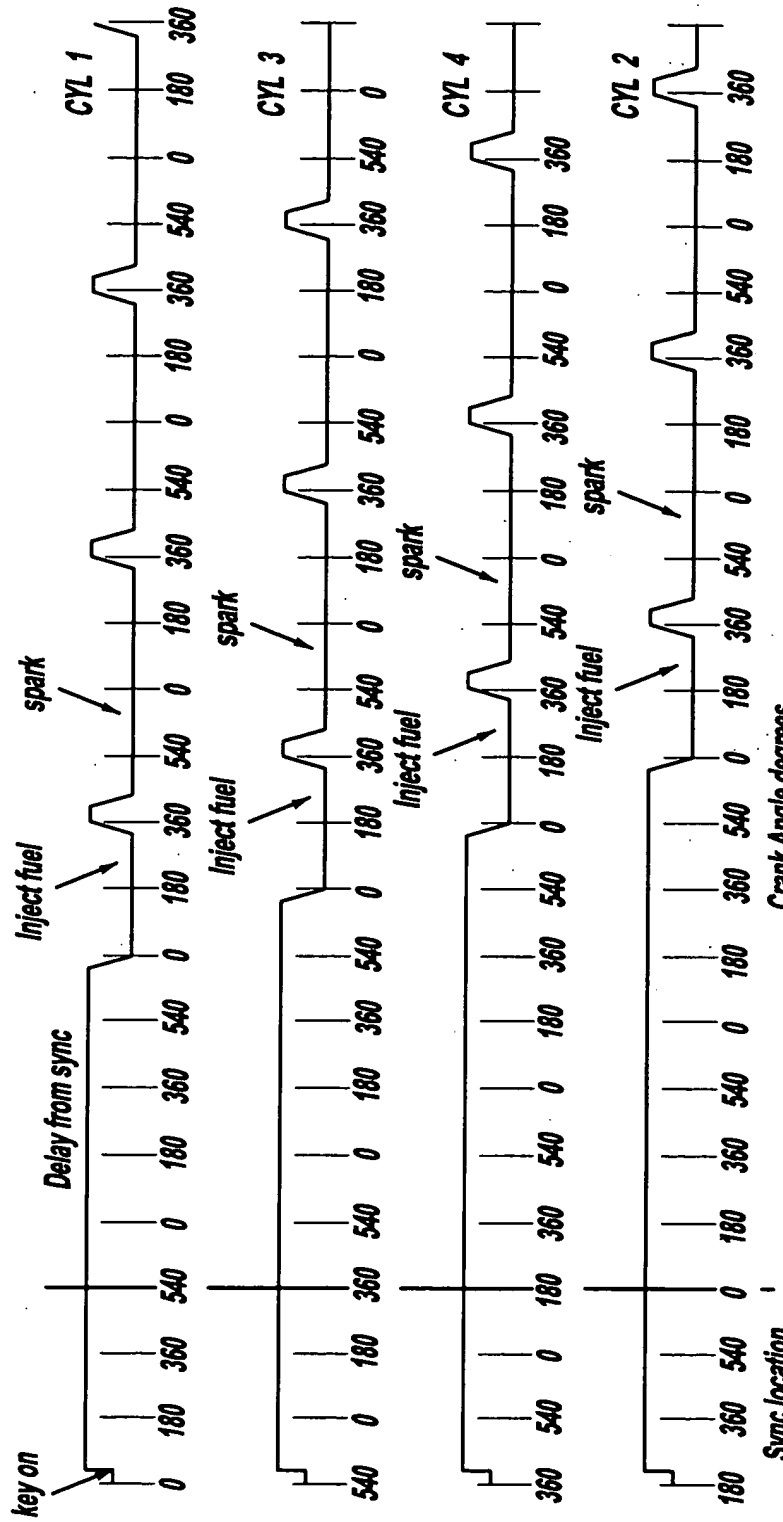
key on
Delay from sync
Inject fuel
spark
CYL 1
CYL 3
CYL 4
CYL 2
Sync location
Crank Angle degrees
Intake Valve Timing From Start (electrical valve operation)

FIG - 49a

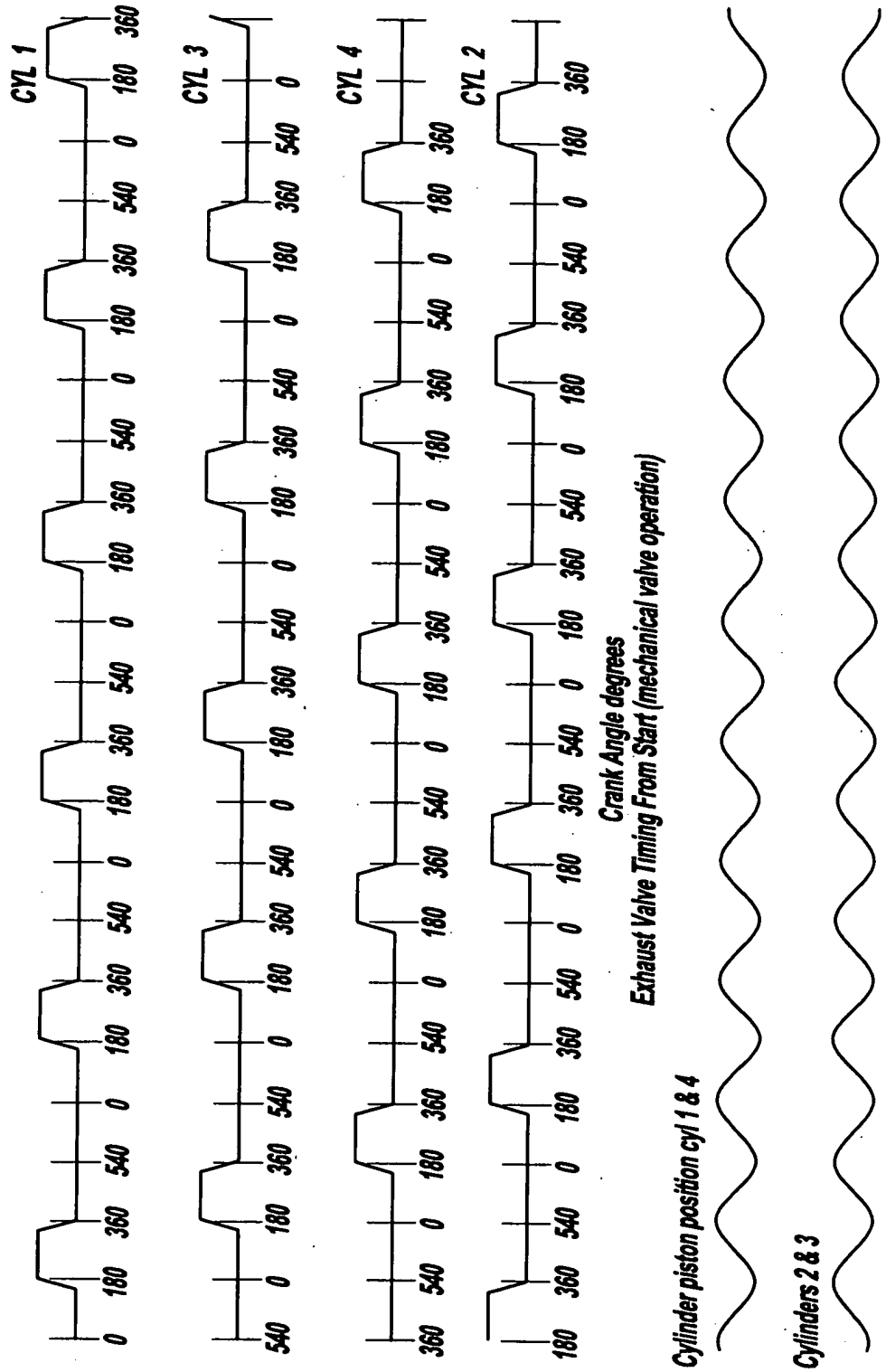
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
180 360 540 0 180 360 540 0 180 360 540 0 180 360 540
Crank Angle degrees
Exhaust Valve Timing From Start (mechanical valve operation)
Cylinder piston position cyl 1 & 4
Cylinders 2 & 3

FIG - 49b

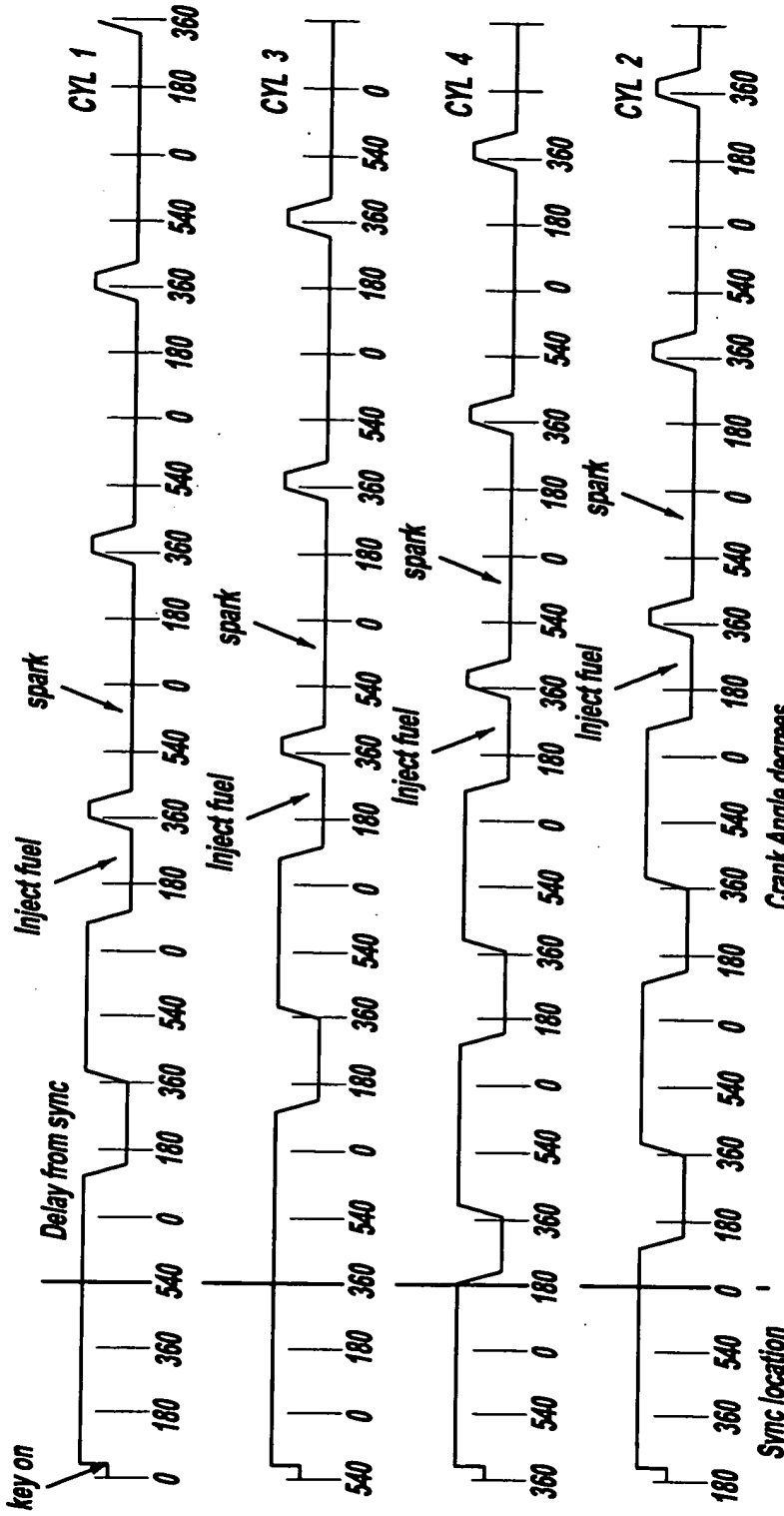
key on
Delay from sync
Inject fuel
spark
CYL 1
CYL 3
CYL 4
CYL 2
Sync location
Crank Angle degrees
Intake Valve Timing From Start (electrical valve operation)

FIG - 50a

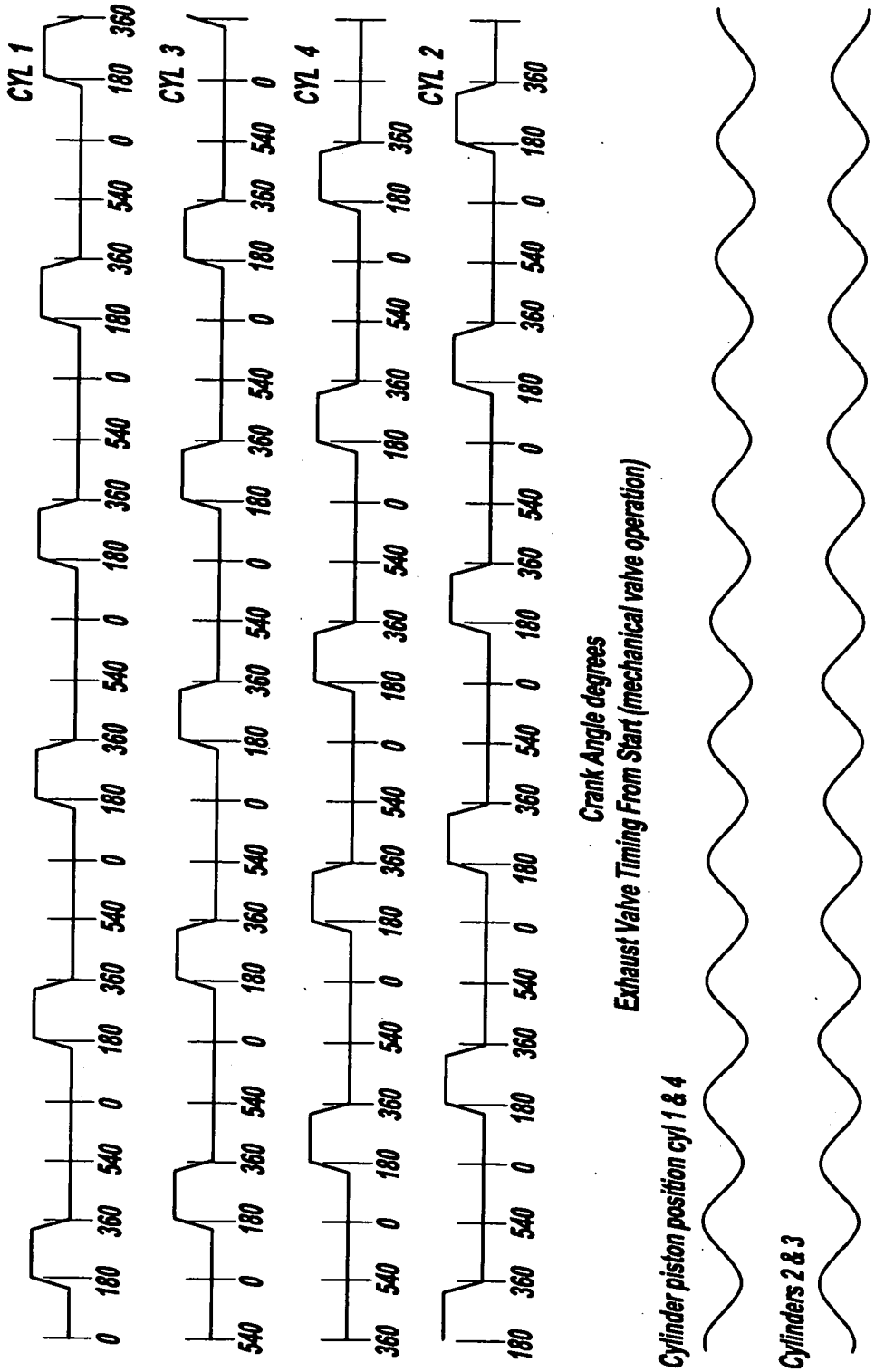
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Exhaust Valve Timing From Start (mechanical valve operation)
Cylinder piston position cyl 1 & 4
Cylinders 2 & 3

FIG - 50b

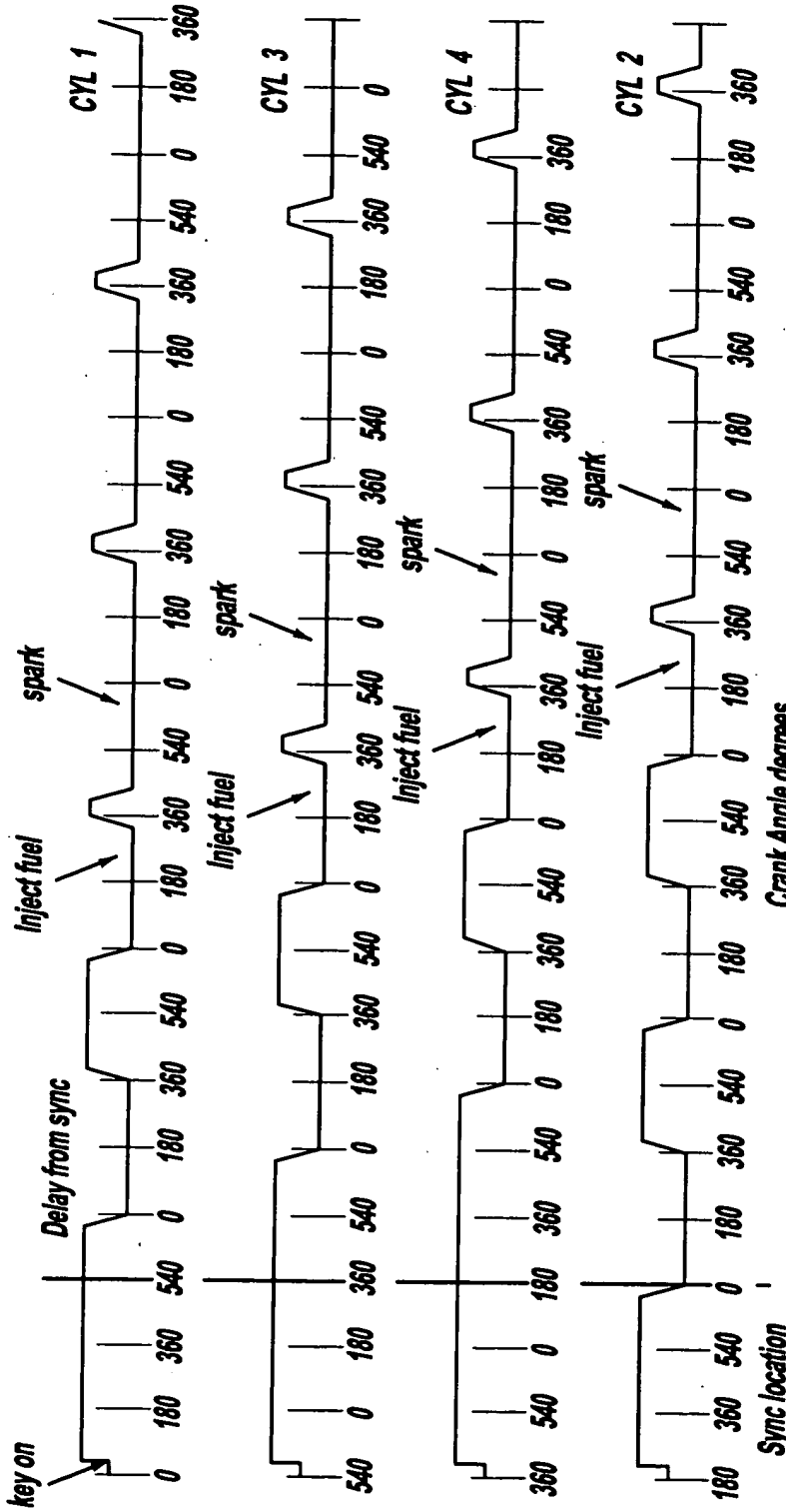
key on
Delay from sync
Inject fuel
spark
CYL 1
CYL 3
CYL 4
CYL 2
Sync location
Crank Angle degrees
Intake Valve Timing From Start (electrical valve operation)

FIG - 51a

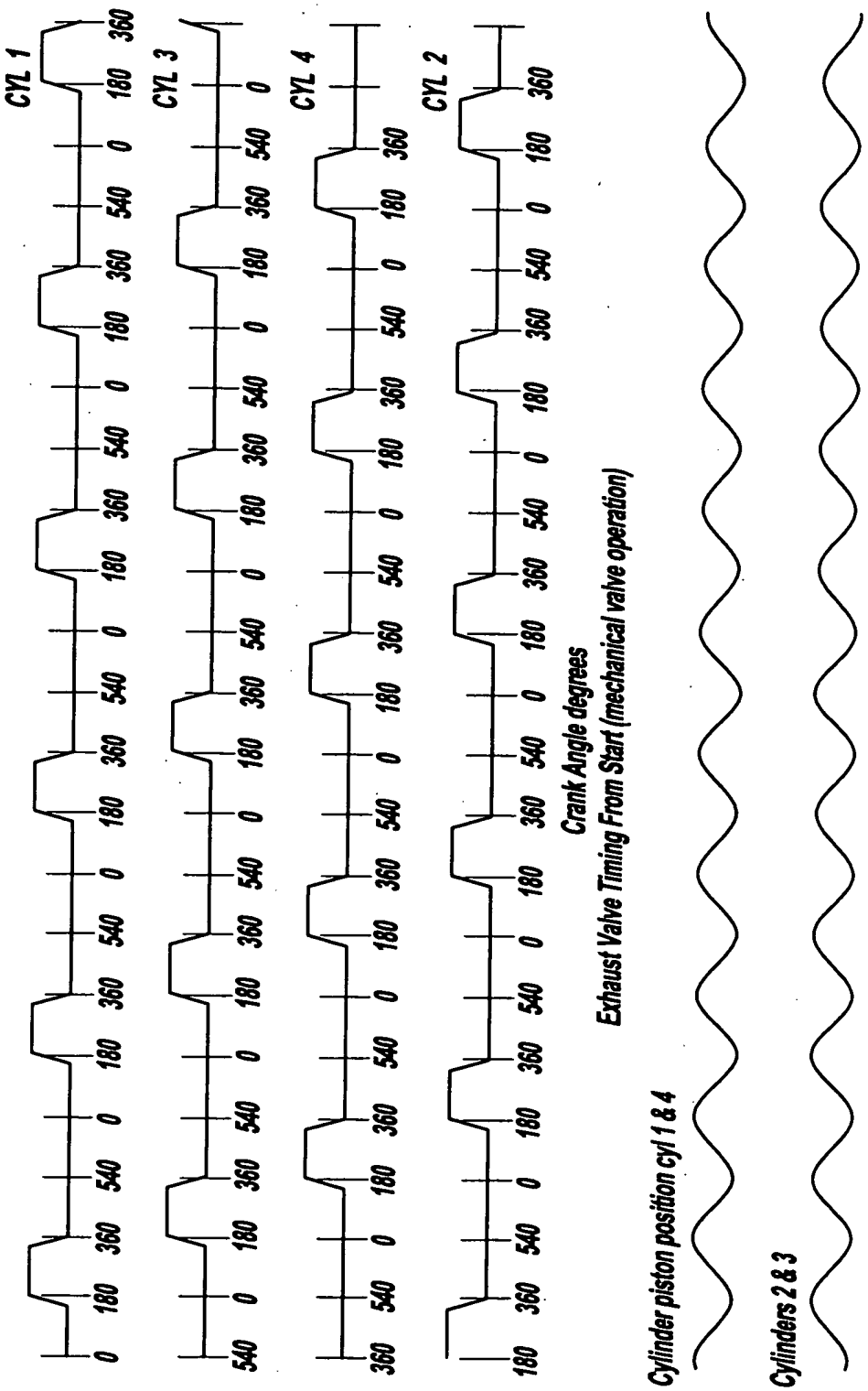
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Exhaust Valve Timing From Start (mechanical valve operation)
Cylinder piston position cyl 1 & 4
Cylinders 2 & 3

FIG - 51b

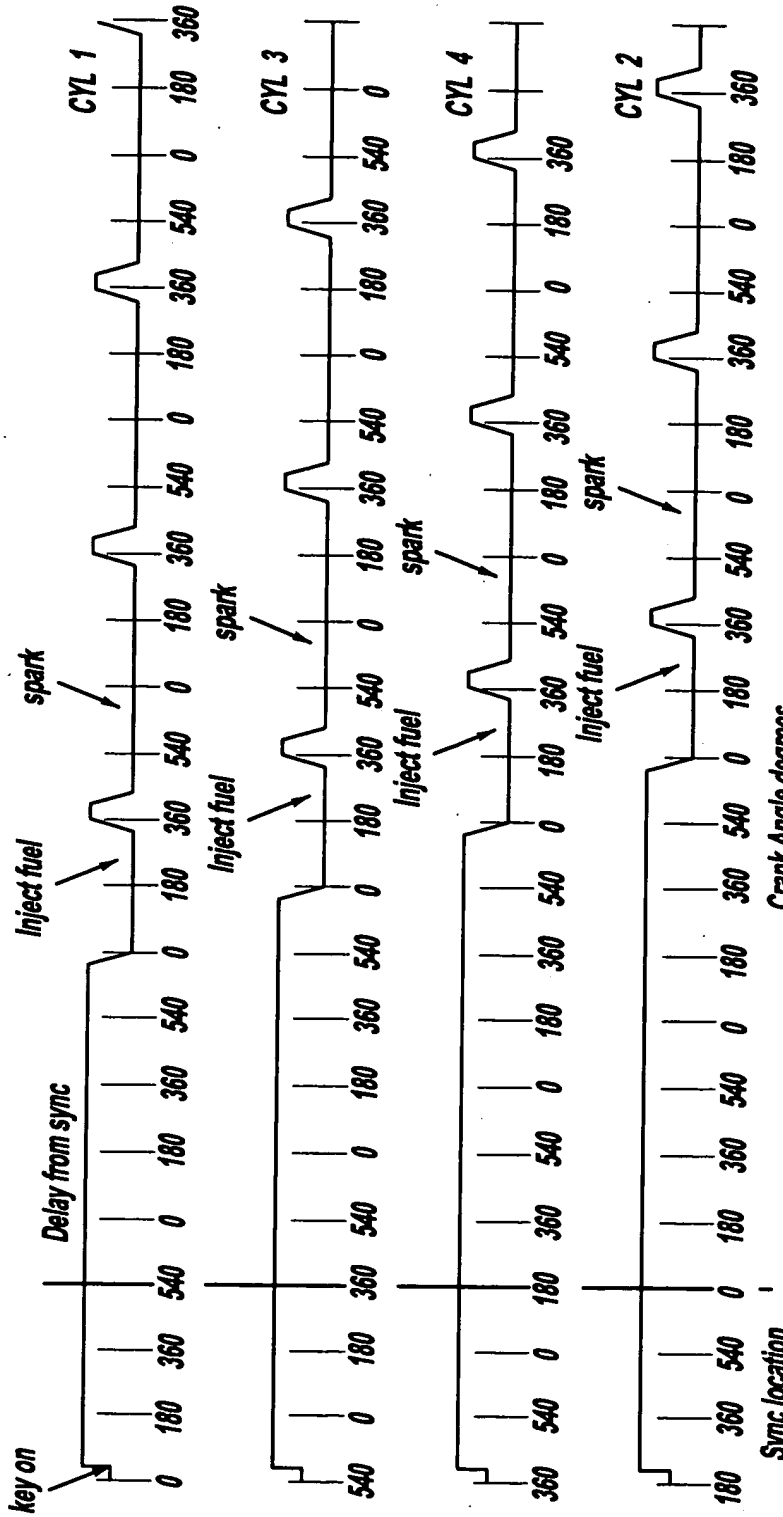
key on
Delay from sync
Inject fuel
spark
CYL 1
CYL 3
CYL 4
CYL 2
Sync location
Crank Angle degrees
Intake Valve Timing From Start (electrical valve operation)

FIG - 52a

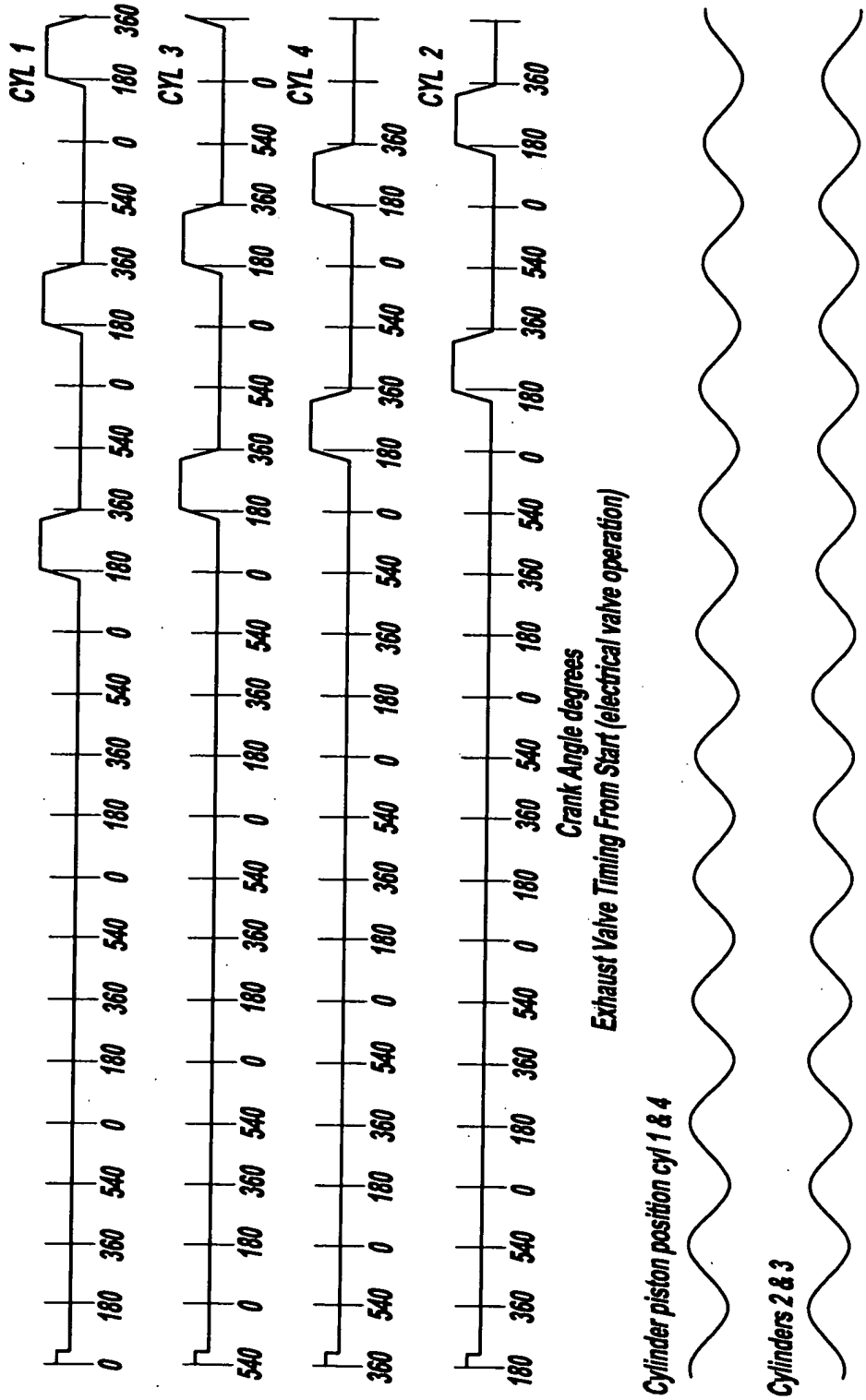
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Exhaust Valve Timing From Start (electrical valve operation)
Cylinder piston position cyl 1 & 4
Cylinders 2 & 3

FIG - 52b

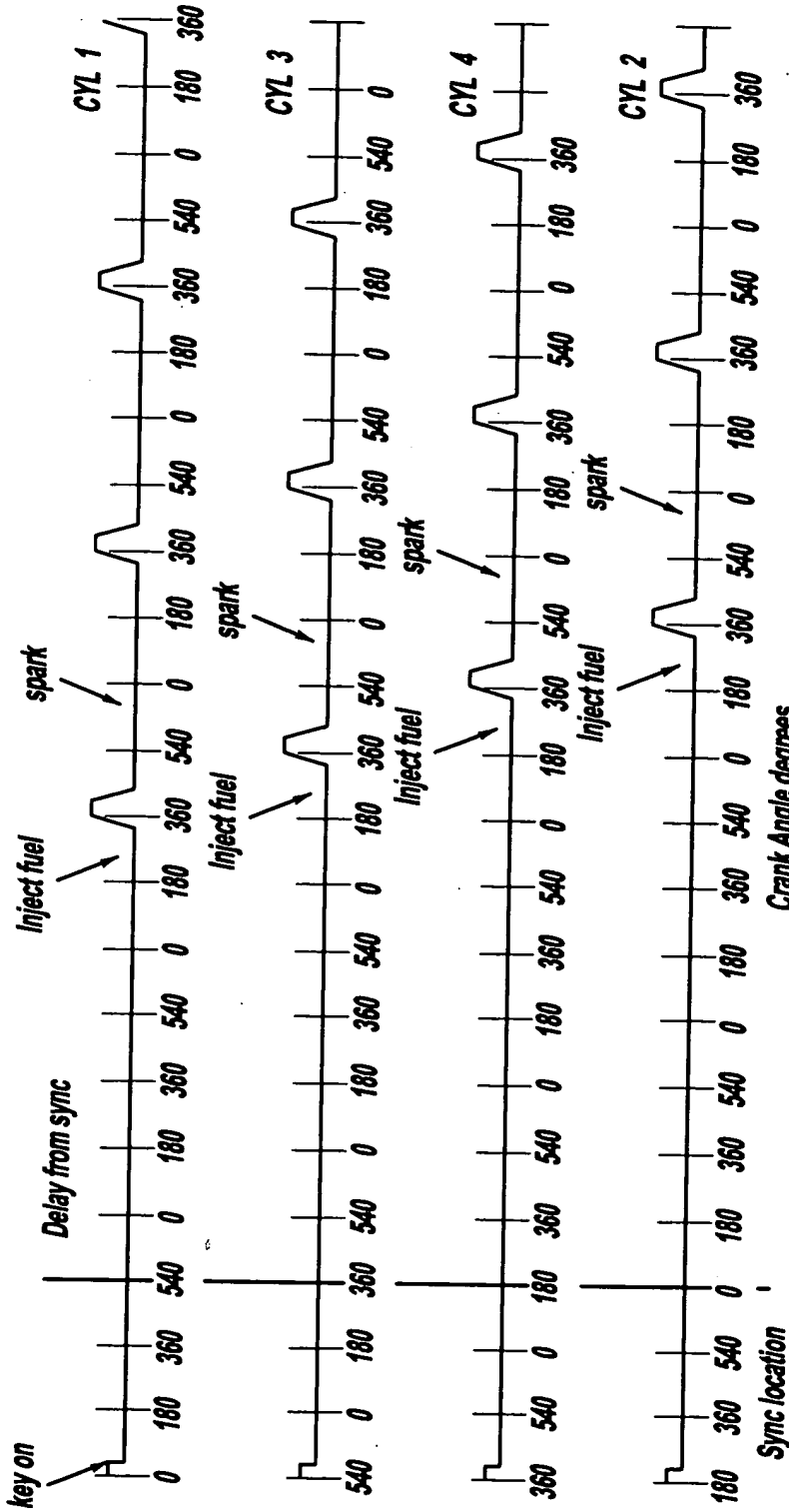
key on
Sync location
Delay from sync
Inject fuel
spark
CYL 1
CYL 3
CYL 4
CYL 2
Crank Angle degrees
Intake Valve Timing From Start (electrical valve operation)

FIG - 53a

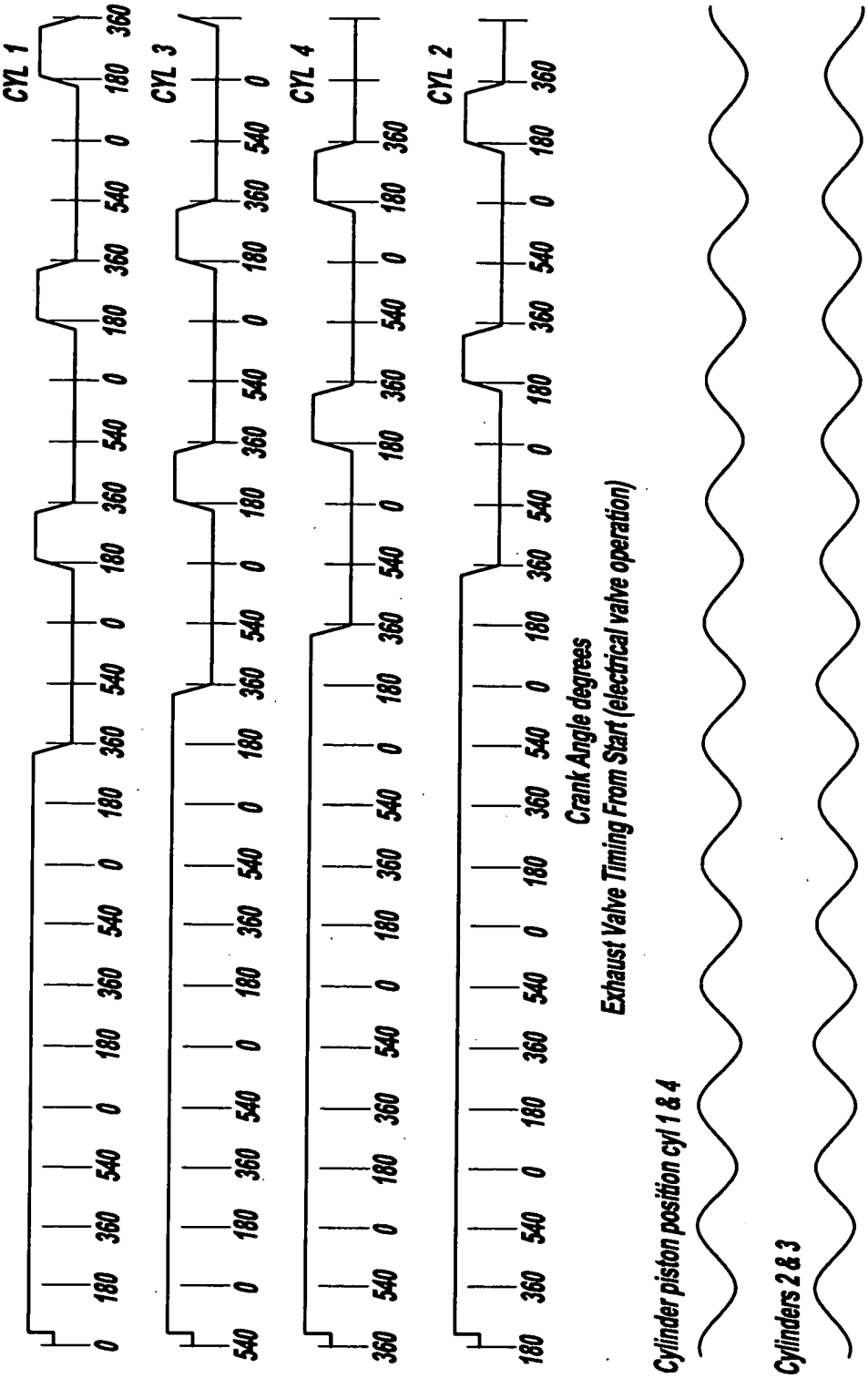
CYL 1
CYL 3
CYL 4
CYL 2
0 180 360 540 0 180 360 540 0 180 360 540 0 180 360
540 0 180 360 540 0 180 360 540 0 180 360 540 0 180
360 540 0 180 360 540 0 180 360 540 0 180 360 540 0
180 360 540 0 180 360 540 0 180 360 540 0 180 360
Crank Angle degrees
Exhaust Valve Timing From Start (electrical valve operation)
Cylinder piston position cyl 1 & 4
Cylinders 2 & 3

FIG - 53b

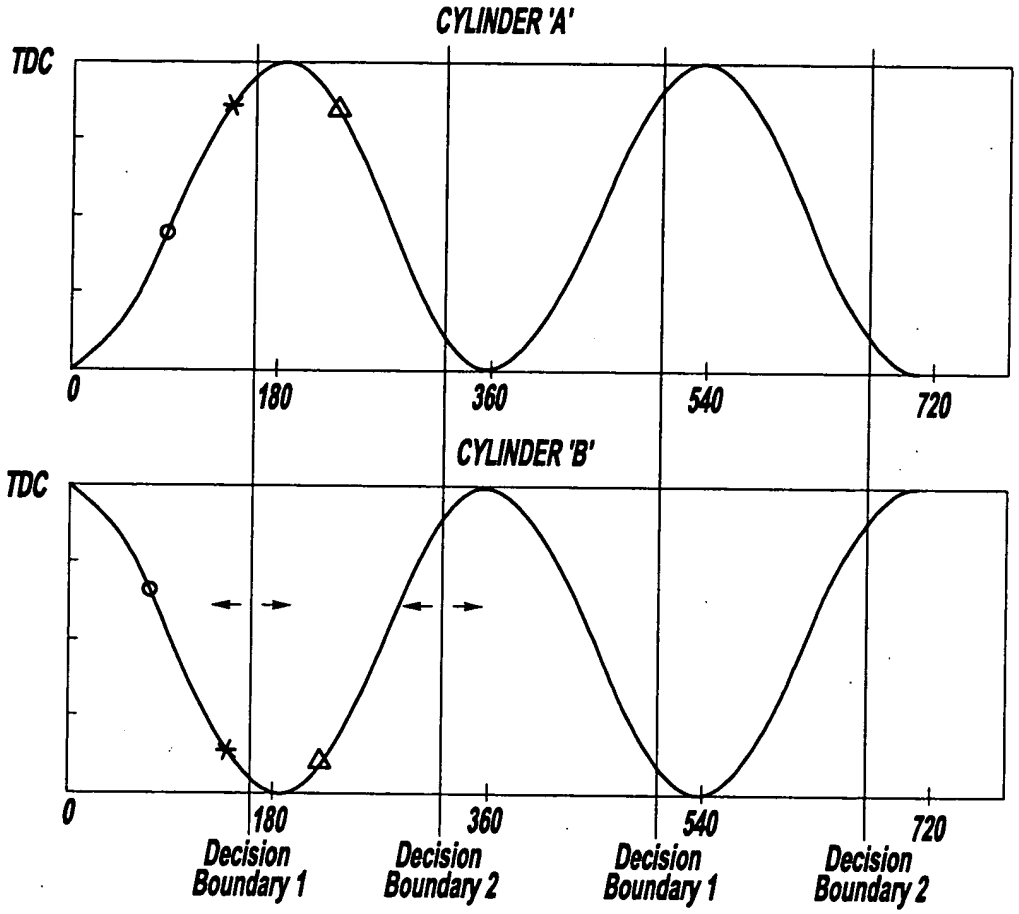
CYLINDER 'A'
TDC
0
180
360
540
720
CYLINDER 'B'
TDC
0
180
360
540
720
Decision Boundary 1
Decision Boundary 2
Decision Boundary 1
Decision Boundary 2

FIG - 54

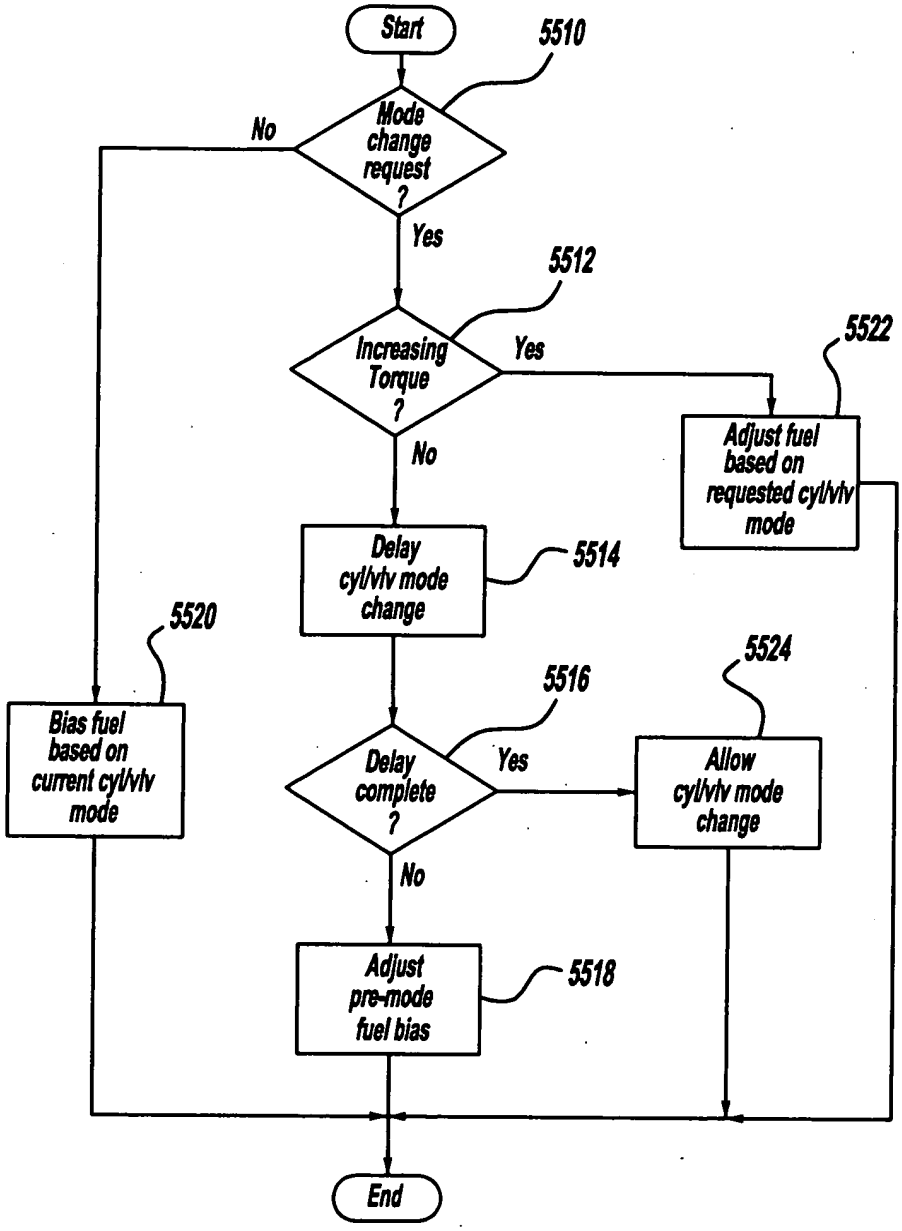
Start
5510
Mode change request ?
No
Yes
5512
Increasing Torque ?
Yes
5522
Adjust fuel based on requested cyl/vlv mode
No
Delay cyl/vlv mode change
5514
5520
Bias fuel based on current cyl/vlv mode
5516
5524
Delay complete ?
Yes
Allow cyl/vlv mode change
No
Adjust pre-mode fuel bias
5518
End

FIG - 55